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THE IDENTIFICATION OF PERFORMANCE INDICATORS FOR THE ENGINEERING AND INSTALLATION OF GROUND CEM SYSTEMS

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LSSR 17-79B

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The Air Force Communications Service (AFCS) mission includes the engineering and installation (EI) of communication-electronics-meteorological (CEM) systems throughout the world. To accomplish this mission requires integrating the efforts of thousands of engineers and installers into a cohesive workforce that utilizes all available resources in an effective and efficient manner. The purpose of this study was to identify the goals and objectives of the Headquarters AFCS staff as they related to the management of EI workforce and to identify performance indicators to increase the effectiveness of that management. A hierarchical and management level framework was developed and both existing AFCS performance indicators and new indicators were integrated into the framework. The research revealed that the AFCS staff had many viable performance indicators and that by matching those existing indicators plus some additional indicators to the goals and objectives, AFCS would be able to continue to perform its EI mission well into the 1980s. As a final recommendation it was suggested that AFCS make greater use of management science techniques and employ the research capability of AFIT to continue development of indicators in subordinate organizations.

LSSR 17-79B

THE IDENTIFICATION OF PERFORMANCE INDICATORS FOR THE ENGINEERING AND INSTALLATION OF GROUND CEM SYSTEMS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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CHAPTER I

INTRODUCTION

"The President can make you a general, but only communications can make you a commander [41:Cover]." That statement by the former Chief of Staff of the United States Air Force (USAF), General Curtis E. Lemay, highlights the importance of reliable and effective communications systems to military commanders in the execution of peace and wartime operations. Air Force Communications Service (AFCS), a major command of the USAF, has the responsibility for managing the complex ground Communications-Electronics-Meteorological (CEM) equipment and systems to support the USAF mission. This management responsibility encompasses the operations and maintenance of CEM equipment as well as the engineering and installation activities needed to support the acquisition and modernization of CEM facilities and systems.

Engineering and installation (EI) activities are spread across the broad spectrum of the modernization effort of CEM facilities. These activities range from the relatively simple removal/installation of a teletype machine to the complex installation of a radar approach control center. The role and importance of this EI

function to AFCS and the USAF can be partially illustrated when one considers that in fiscal year 1978 over 2,000 separate projects were completed by EI personnel (15:7). Also in fiscal year 1978, over $100 million was spent to support over 3,000 military and civilian personnel who spent 60 percent of their time performing installations in a temporary duty status in locations throughout the world (40:1). The ability of EI personnel to accomplish a workload of this nature has evolved out of a turbulent history.

Prior to 1958, the responsibilities for the engineering and installation of ground CEM equipment was fragmented among the Air Force commands. Sixty percent of the engineering and installation tasks were performed by the Air Material Command (AMC), 30 percent by the Airways and Air Communications Services (AACS), the predecessor to AFCS, and the remaining 10 percent by civilian contractors through individual major air commands. In November 1957, in order to improve the efficiency of the CEM engineering and installation efforts, the Air Staff decided to consolidate these activities in an organization called the Ground Electronics Engineering Installation Agency (GEEIA) (7:21-30).

GEEIA was officially activated in March 1958 and, because it was considered a logistics function, it was assigned to AMC. In 1961, when most communication-related

responsibilities were realigned to the newly created major air command, AFCS, GEEIA remained in the Air Material Command (now Air Force Logistics Command) (7:21-30). It was not until July 1970 that the single-manager concept for communications services brought about GEEIA's transfer from AFLC to AFCS. AFCS eliminated the acronym GEEIA, but kept the CEM engineering and installation (EI) function separate from their operations and maintenance activities by establishing a Deputy Chief of Staff (DCS) for Engineering and Programs at the headquarters and intermediate command level, and by maintaining separate EI and operation and maintenance (O&M) squadrons (7:42-51). That concept was still in effect in late 1979.

When AFCS assumed command over the EI function, it naturally inherited all the attributes, both good and bad, of GEEIA. Among the serious problems inherited from GEEIA was the implicit hardship involved in EI work where frequent and extended temporary duty assignments contributed to serious retention and morale problems and placed considerable emphasis on improving the quality of EI life. Headquarters AFCS has vigorously pursued quality of EI life issues and has published AFCSR 500-11, "Commander's Policy--Support for Electronics Installation (EI) Personnel," to address these problems. An AFCS/CV letter dated 24 January 1979 also addressed the quality of EI life issues.

Another attribute inherited from GEEIA was the management information system. Over the years, GEEIA had developed a method of managing its workload that was partially aided by a computer-based system called EIMS (Engineering-Installation Management System). EIMS was developed in the 1960s by GEEIA and is still being used by AFCS as the main management information aid.

EIMS is an automated batch input type system composed of three subsystems: production reporting, workload measurement, and work measurement. The production reporting subsystem produces indicators for budget computations, manpower planning, and cost analysis (17:1-1). The workload subsystem indicators relate to work programmed and/or assigned, work in process and work scheduled for completion (19:1-1). The work measurement subsystem involves work performance standards (18:1-1).

But EIMS is only part of the management system. There are also several manual methods that managers use to gather indicators of the relative health of EI activities (3). These include both telephonic and written reports on the status of the various stages involved in a programmed job. AFCSR 178-3 "AFCS Management Information System," complements EIMS by establishing a system for acquiring indicators which measure mission performance and resource utilization, but its focus is on trends and not a specific job or scheme production.

A job becomes programmed when the need is identified to install, relocate, or remove a CEM facility at a specific location and the supporting base takes action to have that need approved, through the chain of command, at Headquarters USAF. AFCS EI personnel become involved very early in this process by preparing an engineering implementation plan that includes a study of the requirements, equipment siting criteria, recommended equipment, and cost estimates (14:35). Once the program is approved, EI personnel prepare the scheme (detailed instructions that outline the specific procedures and materials to be used to accomplish the task), monitor the completion of any allied construction needed, order and gather the necessary materials, and finally deploy a team of personnel to complete the work. This entire process may take years to complete, depending upon the complexity of the project and/or related programs (14:36-41). Effective management of thousands of these types of actions every year has been a continuous EI goal. The flow of the information necessary to control and forecast a workload of this magnitude requires numerous status indicators of the systems' performance. Over the years, there have been numerous instances where target dates were not met and/or unprogrammed resources were consumed. In addition, many other problem areas have made EI management a real challenge (24).

Such problems, plus the dissatisfaction of many upper level managers caused by their inability to control events before they became disruptive, were noted through the years in several Inspector General and audit reports. This led to a 1976 contracted study which had as its purpose the development of an information processing system to improve the capability to forecast and control the EI workload. That report reconfirmed previously perceived problem areas and recommended that a new automated management information system be adopted. The estimated cost of such a system in 1976 was $3 million (16). Mainly due to cost considerations, the recommended system was not implemented.

In February 1977, AFCS initiated a project known as Introspective Look which consisted of an in-depth self analysis of AFCS. The analysis included rigorous management audits of functions and programs (25:1). Among the actions resulting from this was an in-house project to improve the current management information system. This project was scheduled for completion in the latter part of 1979. In late 1978 the AFCS Commander again reconfirmed the need for improving the management information system and to identify meaningful EI performance indicators (23:1). In January 1979, a conversation between the researchers and key AFCS staff personnel confirmed the need to identify better performance indicators for EI

activities and they stated that they would sponsor an independent attempt to identify performance indicators (5).

Problem Statement

There is a need to identify meaningful performance indicators which will assist the Headquarters AFCS staff in improving the management of the engineering and installation of CEM systems.

Scope

The scope of this thesis was limited to AFCS EI functions at Headquarters AFCS; it excluded the mobile depot maintenance (MDM) responsibiities of EI. MDM was not addressed since part of its workload is controlled and monitored by the Logistics staff which is a maintenance-oriented directorate and therefore not attuned to the issues involved in EI management.

CHAPTER II

LITERATURE REVIEW

Once the research problem had been formulated and the scope defined, a review of related literature was undertaken. The goal of this review was to determine what other authors had written concerning CEM engineering and installation management, effectiveness measurements, performance indicators and output measurements. This search began with an inquiry into the Defense Documentation Center (DDC) and the Defense Logistics Studies Information Exchange (DLSIE). In addition, the National Technical Information Service (NTIS), theses abstracts, business periodical indexes, and other standard library research aids were reviewed. The information gleaned from those sources enabled the researchers to identify numerous related sources that could provide an initial baseline for the thesis research.

A 1972 thesis by Ullrey and Penas entitled, "A Hierarchy of Objectives and Related Indicators for Aircraft Maintenance Organizations" and Robert Anthony's book, <u>Management Control in Nonprofit Organizations</u> were initially the basic sources used in developing a framework for analysis.

Ullrey and Penas examined base-level performance indicators. Their study was limited to base-level maintenance organizations involving support of aircraft operations (34:23). They identified eighty-nine indicators grouped into twenty-two categories, each patterned after the goals of the organization. Among the categories were optimum use of resources (materiel and personnel); efficiency of personnel scheduling; effectiveness of personnel training; control and coordination of manhour losses; and optimization of the number of people assigned to direct labor (34:71). Ullrey and Penas used a hierarchical framework patterned after the organization's goals and objectives.

Anthony's approach was similar to the one used by Ullrey and Penas. Dr. Anthony also recommended that performance indicators be patterned after the goals of the organization. He suggested that indicators can take on many forms. They can be subjective or objective; quantitative or nonquantitative; and discrete or scalar. They can measure quantity or quality or be result- or process-centered. To evaluate existing or proposed performance measurements he recommended a framework of analysis and a structured approach (3:144). Anthony's approach for identifying performance indicators complimented the Ullrey and Penas approach as both recommended the use of a framework.

Several other AFIT sources addressed the task of developing a performance indicator system. Most of these focused on aircraft maintenance organizations, but many had possible application to CEM engineering and installation management. Three AFIT theses, "Measuring Aircraft Maintenance Effectiveness" by Connell and Wollam, "A Study to Provide a Technique for Evaluation of a Maintenance Information and Control System" by Chaney and Cheney, and "A Determination of the Measurable, Operational Characteristics of Information Required by Wing Level Maintenance Management" by Johnson and Thompson made some contribution to the development of an EI framework for identifying indicators.

In 1968, Connell and Wollam sought out effectiveness measurements which could be used by maintenance managers at each level of command. They were also interested in determining if maintenance managers at each level were in agreement on the definition of maintenance effectiveness. Through interviews and using a survey method, Connell and Wollam were able to identify over thirty effectiveness measurements related to performance, quality, management, support, and personnel. They also found that performance, quality, and management were the most important to managers at all levels in evaluating the maintenance organization's ability to meet mission requirements. Another finding was that managers at each

level of command define maintenance effectiveness in terms of different measures (12:100). These thoughts were kept in mind during this research effort.

In 1971, Johnston and Thompson identified twenty-three measurable performance indicators for managing a wing-level maintenance organization. They gave no consideration to how this information could be collected and suggested it be a subject for further research (27:129-131). Selected indicators identified by Johnston and Thompson seemed to be applicable and gave some clue as to the development of indicators for EI.

In 1969, Chaney and Cheney conducted a study which singled out seven measurable characteristics of information: quantity, accuracy, relevancy, timeliness, simplicity, compatibility, and quality (9:63-64). These were based on extensive research, analysis, and groupings. They recommended that future research should consider similar factors in evaluating maintenance information and control systems (9:68). Although this recommendation was limited to maintenance systems, it was found to have some application in this research effort.

The works of several authors, considered to be experts in their areas of study, were also reviewed in order to gain a firmer understanding of the theory and philosophy of performance indicators and organizational

management. A few of the more pertinent are summarized below:

C. West Churchman, in his article entitled, "Systems," outlines five considerations that describe a system in a healthy working condition. According to Churchman, a healthy system is comprised of objectives, performance measurements, environmental constraints, system resources, activity components defined in terms of goals and performance measurements, and system management (11:18). Churchman's discussion of goals and objectives as they relate to performance measurements helped the researchers gain greater insight into the subject area. It also echoed the general theme that any effort to find performance indicators must begin by ferreting out the organization's goals.

In "Resistance to Rational Management Systems," Chris Argyris advises that an organization tends to resist any effort to reveal knowledge about itself and he elaborated on several fears. The most basic fear was that an effective management information system (MIS) identifies past mistakes. Another fear may come from executives who view information as a tool of institutional power. He recommended that:

> The first step is for all concerned to become aware that MIS is not the basic problem. The basic problem is that organizations are full of concealed dysfunctional actions and defenses that are revealed by MIS. Perhaps if ways could be found to make

> quantitative models more accurately reflect the world as line managers experience it, their fears and resistances would be lowered [4:393].

From this, the researchers recognized that finding the real goals may be a difficult task.

Fremont Kast and James Rosenzweig in their book, Organization and Management--A Systems Approach, emphasized the importance of recognizing the distinction between indicators used for planning/forecasting and those needed for management control purposes. Kast and Rosenzweig also viewed the organization as a composite of strategic, coordinative, and operating levels (28:120). In terms of the engineering and installations of CEM systems, Headquarters AFCS is the strategic level; the communications areas, the coordinative level; and the EI Groups, the operating levels. Therefore, some recognition must be given to the differences among the goals as they relate to the various management levels. They recommended that these distinctions be considered in evaluating a MIS (28:375).

In A Basic Approach to Executive Decision Making, Oxenfeldt, Miller, and Dickinson discussed the need for following a framework in decision making.

> Just as road signs are of little or no value unless you know where you are driving, a decision cannot generally take you where you want to get unless you know what your goals are [33:14].

They further developed the concept that certain goals are "ultimate" and do not meet the needs of the

decision makers for direction and guidance in selecting among alternatives. Therefore, intervening goals or objectives must be developed which reflect the basic strategy of the organization. Some of these objectives may be in conflict with each other if they are at the same level; therefore, the authors pointed out the need for a hierarchy of objectives that lead to the higher-level purpose or goal (33:27). They then indicated the importance of having a model of how the system operates and how different conclusions can be drawn on the same data base if the decision makers are using different models (33:56).

With the goals and objectives developed and based upon a common model, the authors highlighted the need for a series of indicators to assess the health of the organization. These indicators are part of what they describe as a signaling system which is made up of a reporting system and a signal level. In a typical organization this reporting system is made up of quantitative reports and a fact finding method (an IG in military terms), but these systems typically overload executives with irrelevant information and provide too little of the right kind of information. They pointed out that a good reporting system has three parts: ". . . identification of the aberration (good or bad), description of the symptoms of the disorder, and selection of an indicator (index number) for the disorder (33:75)." To create the signal level that

can alert the executive many factors have to be considered and they recommended that each signal level be based upon the factors that really describe the problems and that the actual level consider random variables, standard deviations, and normal distributions (33:75-76).

H. Higor Ansoff's book, Corporate Strategy: An Analytic Approach to Business Policy for Growth and Expansion, studied corporate decision making by breaking the process into three categories: strategic, administrative and operating. These categories are very similar to Kast and Rosenzweig's strategic, coordinative and operating levels. Ansoff explained strategic decisions are mainly concerned with how the organization relates to the external environment. In other words, the strategic goals are established in a broad sense to insure the organization survives in the marketplace (1:5).

In Ansoff's model, the administrative decision processes are internally oriented and focus on structuring the organization's resources to create maximum performance potential. This included handling organizational problems such as authority and responsibility relationships, work flows, information flows, and the acquisition and development of resources, such as people, facilities and equipment (1:6).

At the operating decision level the objective was to maximize the resource conversion process and concerns

the decisions involving setting inventory levels and production schedules, deciding on prices and expenses for marketing and operations, etc. (1:5).

Ansoff then established the need for a practical system of objectives and discussed how an overall hierarchy of objectives should be developed that considers long term, proximate (short term), and flexibility objectives and both economic and non-economic objectives. The bottom layer of the hierarchy of objectives is revealed to be a series of indicators (e.g., current earnings, capital gains, philanthropy, etc.) that are generally quantifiable (1:43-74).

Ansoff's hierarchy of objectives was reiterated ten years later in Siegel's 1975 book entitled, Strategic Planning of Management Information Systems, as a way to define measures of future capability (37:209). Siegel focused on the proper way to implement and/or use a management information system (MIS) but he, too, used a very structured approach that started down the hierarchy from goals through indicators. It was his contention that one has to study an organization and the environment it operates in, before the strategic level objectives can be formulated and then translated into a MIS that can provide an indication of where management action is needed (37:165).

Siegel explained how a measurement study should follow a set pattern and how it was important to be able

to measure the overall organizational performance as well as its future capability and its measures of responsibility. He stated that:

> Responsibility may be measured by following the hierarchy of the management structure; by statistically separating the influences of the six MIS levels; and by separating the strategic from operational goals and measures [37:22].

He used a systems approach that naturally involved inputs, processors, and outputs, and while his main concern was the MIS, he was very careful to show how these elements react to the environment and how a control system provides additional feedback loops to help keep the entire structure viable within the basic philosophy of management (37:196).

Another approach to the issue of setting organizational goals and then establishing a criteria of accomplishment measurement was put forth by William E. Rothschild in his book, Putting It All Together: A Guide to Strategic Thinking. He suggested that when the upper level managers are in their strategic planning phase that they attempt to determine what the critical success factors (CSF) are for that organization. To do that, managers must ask themselves to define what it would take for any organization in the same basic endeavor to succeed (36:168).

The CSF method was being researched and applied in 1979 by research teams at the Massachusetts Institute of

Technology's Sloan School of Management. They spent several years helping executives define their goals and then determining the critical success factors that supported those goals. The goals were ferreted out by conducting interviews that focus on the purpose for the organization. With the goals established, the underlying CSFs could be brought out by focusing on the individual manager and his/her informational needs. These goals represented the end points that an organization hoped to reach, but the CSFs represented areas in which good performance was absolutely necessary to ensure attainment of the goals (35:85).

CSFs are very similar to objectives and fit well in Dr. Anthony's management level framework. In fact, in a 1979 Harvard Business Review article on CSFs, Anthony and his colleagues were given credit for expanding on the earlier ideas of CSFs in their work on designing the three "musts" of a management control system (35:86).

> The control system must be tailored to the specific industry in which the company operates and to the specific strategies that it has adopted; it must identify the "critical success factors" that should receive careful and continuous management attention if the company is to be successful; and it must highlight performance with respect to these key variables in reports to all levels of management [35:86].

The structured approach to measuring effectiveness has also been touted by the operational research community and was expressed very clearly in George K. Chacko's

book, <u>Applied Operations Research/Systems Analysis in Hierarchical Decision-Making</u>.

> To avoid the myopic mistake of defining the effectiveness of the subsystem to the exclusion of the recognition of the hierarchical relationships between tactical, strategic, and organismic hierarchy of objectives, it becomes mandatory to order the objectives of the system as a whole, to which the accomplishment of the subsystem objectives is contributory in a subordinate way [8:109].

Paul E. Mott, in his book, <u>The Characteristics of Effective Organizations</u>, stated:

> The concept of effectiveness is multidimensional, involving, besides productivity, the organization's ability to adapt to changing conditions both internal and external (adaptability) and to cope with temporarily unpredictable emergencies [31:ix].

Due to frequent changes in the EI management structure, the concept of adaptability described by Mr. Mott helped in the understanding of the dynamic EI organization.

Finally, in their 1972 study of the CEM programming process, Prather and Guillory found the process was complex and the procedures were nonstandard. One of their recommendations was that a complete and detailed study be made of EIMS with the objective of "eliminating duplication and simplifying the format and readability of the reports (14:93)." They perceived that CEM EI management could be improved if the management indicator system was easier to use and understand.

Based on this literature review, research objectives and questions were formulated.

Objectives

There were four major research objectives involved in this thesis.

The first objective was to determine Headquarters AFCS goals and objectives for engineering and installation of complex CEM equipment.

The second objective was to identify any existing performance indicators.

The third objective was to compare these existing indicators with the identified goals and objectives.

Finally, the fourth objective was to recommend performance indicators which match the goals and objectives of the Headquarters AFCS staff.

Research Questions

1. What are the goals and objectives of the Headquarters AFCS staff in the engineering and installation of CEM systems?

2. What EI performance indicators support the goals and objectives of the Headquarters AFCS staff?

CHAPTER III

METHODOLOGY

Philosophy of Methodology

The development of the methodology was based upon an extensive review of the literature concerning management and the methods of measuring the effectiveness of management. One of the objectives of that literature search was to determine if any common threads existed among the various authors. It was felt that if a common theme was prevalent, then an approach could be developed based upon that commonality.

A common thread was found; it was centered on a goal-oriented viewpoint that was the start of a hierarchical approach to the development of performance indicators. The hierarchy basically shows that in order to develop realistic, useable performance indicators, one must start at the top of the organization and determine the goals and objectives of the upper level managers, and then develop measurement criteria or performance indicators that support those goals and objectives.

The key to this whole process is to initially ferret out the goals from the people who are in the so-called strategic planning levels of an organization. For if you

don't know where you are going (goal) then it doesn't matter how you get there and you probably won't recognize it when you arrive. Therefore, it is vital that any successful organization have its direction and destination firmly in mind before attempting a new venture or continuing down its present path.

Hierarchical Framework

The researchers used the Ullrey and Penas thesis as a jumping off point for development of a hierarchical framework and structured a hierarchy by:

1. Establishing the organizational goals
2. Developing the objectives
3. Developing the performance indicators

Attempts to put one step ahead of another generally creates confusion and/or a set of performance indicators that do not enable management to assess real progress toward their mission accomplishment.

Goals

With the hierarchy firmly established, the meaning of each level of the hierarchy needed to be crystalized. There were numerous definitions of a goal, but the one that seemed most in line with this research study was:

> Basically, goals are plans expressed as results to be achieved. In this broad sense, goals include purposes, missions, objectives, targets, quotas, deadlines. etc. Goals represent not only the

> end point of planning but the end toward which other managerial activities such as organizing and controlling, are aimed (28:440).

Goals can be conceived at any level of an organization but they were generally very broad in scope and were not easily quantifiable; therefore, they were thought of as being mainly in the domain of the strategic planning levels. In order to get at the organizational goals, several methods can be employed. One of them was to look for written statements that express the purpose for which the organization exists. In the case of a military unit these goals are often established as part of the mission statement in a regulation.

The problem with written goals is that they are often so-called "motherhood-and-apple-pie" statements that sometimes do not coincide with the real purpose of the organization. To uncover the "real" goals, a researcher could either spend innumerable hours observing the activities of an organization in an attempt to find out how it actually acts or reacts, or develop and administer a written questionnaire or conduct interviews of the executives at the strategic planning level. For it is naturally assumed that the individuals at this level are a rational set of decision makers who have in mind a set of goals that are few enough in number to be manageable and that the goals can be defined well enough to be understood (13:19). In using the interview method, the interviewer

confronts an open-minded manager who should be able to extemporaneously recite the goals which should mean most to him/her and these should be the most important ones. Therefore this was the approach selected by this research team. It was practical because the population involved was small and there was sufficient time to enter into a two-way communication process that did not restrict the interviewee from expressing his/her viewpoint in any way.

Objectives

Once the real goals have been identified, it is necessary to determine the objectives of an organization, but before these objectives can be identified, the definition of an objective needs to be firmly established. Namely: "An objective is a specific result to be achieved within a specified time, usually one year or a few years [3:136]." The term objective is often used to express the same thought as that of a goal and many people use the terms interchangeably; however, for the purposes of clarity in this paper the above stated definition was used.

For an objective to have real meaning to an organization, it should be stated in measurable terms. This implies that if the objective is not stated in quantitative terms, then the performance towards achieving it cannot be measured; however, that is not true as the performance could be judged, appraised or evaluated in some

other manner. It is often very difficult to attach a quantitative measurement to an idea that, for example, is mainly concerned with a so-called "quality of life" issue. The important thing is that there should be someway of assessing whether or not an objective has been achieved. If that assessment cannot be made, then the objective had no real meaning as a management tool. (3:136).

Another crucial point with an objective is that it should be consistent with the organizational goal(s) and it should represent something that requires managerial judgment and action, not just an ordinary, ongoing activity of an organization. In other words, an objective should be nonroutine (3:137).

Indicators

The last step in this hierarchical approach is the identification of the performance indicators. A performance indicator is an output measurement and allows managers to focus on the effectiveness and efficiency of their organizations. A performance indicator is ". . . an element of an activity that can be measured, and when given a numerical value, might serve to measure progress toward an objective . . . [34:83]."

Indicators can be expressed in a variety of ways. They can be of a discrete nature, such as simple red light or green light that immediately tells a manager that

performance of an activity is acceptable or unacceptable. They can also be a complex series of figures or a scale that represents progress (or the lack of progress) towards a specific objective (3:138).

Indicators can serve to measure quantity or quality. While it is much easier to measure quantity because all one has to do is count what was present, any indicator of quantity usually carries with it an implication of quality (e.g., twenty schemes were completed <u>satisfactorily</u>). The term "satisfactory" may not be well defined, but it is an important aspect of the indicator. Quality, too, can be defined in a discrete manner (e.g., satisfactory/unsatisfactory) or it can be expressed in a scalar manner (e.g., zero scheme exceptions, 1-3 exceptions, 4-6 exceptions, etc.) These ratings can be determined subjectively or objectively. The subjective method does not require human judgment after the standard is once set; however, the objective method of assessing quality as based upon an overall human judgment rating is usually superior to a purely subjective approach to quality. (Numerical ways of measuring beauty are generally far inferior to an overall visual judgment.) (3:138-139).

Indicators can be result- or process-centered or both. Result-centered indicators measure the outputs as they are directly related to organizational objectives. They are ends-oriented. Since the ideal objective is

expressed in measurable terms, the indicators directly express this measure; however, sometimes the results cannot be expressed directly and one or more surrogate indicators need to be developed to express an end result (3:141). For example, if an objective was to improve morale by the end of 1980, several surrogate indicators such as the number of people AWOL or the number of reenlistees in E-1 skills could help to establish whether or not that objective was met.

A process-centered measure relates to activities carried on by the organization. It is means-centered. It differs from the result-centered indicators in that it measures the means by which an organization accomplishes something. For example, the number of items ordered this week, the number of schemes inspected last month, the number of manhours spent on engineering in June, etc. There is an implicit assumption that these process-centered indicators help to achieve the organizational objectives, but they have to be carefully developed to make that assumption valid. Carrying on the earlier example, if the result-centered measure was the increase in the reenlistment rate, a process-centered measure might be the number of reenlistment interviews per month. There may be a causal relationship between the number of interviews and the reenlistment rate, but it may be small and not really valid (3:141).

Indicators can also show trends or output ratios and may be derived from simple observations or through sophisticated statistical approaches. Many indicators are produced by computers and are based on thousands of data inputs that have been combined to produce one figure of merit. In other cases, a manager may get a "pile" of computer products that should indicate to him how the organization is performing. Some of these are good and some are not, but the important thing is that unless the indicator can be tracked through the hierarchy of objectives and goals, it is not an indicator that will help the manager in his quest to accomplish the mission in an effective and efficient manner--in fact it may interfere with the whole process.

Management Levels Framework

Many of the publications researched in the process of establishing the methodology referenced the works and words of Dr. Robert N. Anthony. Dr. Anthony, therefore, was recognized by the researchers as one of the key thinkers in the area of management control, especially in light of his prior service in the Office of the Secretary of Defense (OSD). Using his books, Management Control in Nonprofit Organizations and Planning and Control Systems: A Framework for Analysis as a jumping off point, it became clear that an organization, such as Headquarters AFCS,

should have its planning and control processes established within a framework that consists of a strategic planning level, a management control level, and an operational control level (2:15-17).

It is at the strategic planning level that the major goals of the organization are formulated and promulgated to the lower echelons and Dr. Anthony defined strategic planning as the:

> . . . process of deciding on objectives of the organization, on changes in these objectives, on the resources used to attain these objectives, and on the policies that are to govern the acquisition, use, and disposition of these resources [2:24].

As used in this definition, the term "objectives" describes what the organization wants to accomplish (the mission) and the term "policies" describes the guidelines used to determine the path for accomplishing those objectives (2:16).

Management control, on the other hand, is also involved in planning, but is more concerned with the ongoing management of the organization from the internal viewpoint. Dr. Anthony defines management control as:

> . . . the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives [2:17].

The key ideas in that definition are that managers accomplish their tasks by working with other people within the policies and objectives set by the strategic planning

process and that the criteria for measuring the results of that action are effectiveness and efficiency (2:17).

The last control level in Dr. Anthony's framework is the operational control level. This area has a somewhat vague definition:

> Operational control is the process of assuring that specific tasks are carried out effectively and efficiently [2:18].

At the operational control level of an organization, such as an AFCS EI line manager, the primary focus is on doing a specific task (e.g., ordering 500 feet of cable for a specific scheme) where little or no judgment is required because the cable length and type were specified at the management control level.

To bring these concepts into a little sharper focus think of the AFCS command section as the strategic level which sets a goal of improving the management of EI by having a better forecasting system for new requirements. At the management control level the managers might plan to have a new system centered around a micro-computer and be installed by contract in 1982. At the operational level the task of ordering the micro-computer and its accessories would be handled. At all of these levels, some form of performance indicator would be needed to inform each level of progress and to identify impediments to goal and objective accomplishments.

Application of Methodology

The methodology has been organized to address five major considerations: description of the population, the data, the criteria for the admissibility of the data, specific treatment of the data for each research question, and assumptions. The structured approach was based on the philosophy described above.

Description of the Population

The universe and population for this research are depicted in Figure 1. The universe is the Headquarters

	Universe	Population
Command Section	X	X
DCS Engineering and Programs	X	X
Program Control	X	X
Engineering	X	X
Program Management	X	X
Satellite Programs	X	
DCS Operations	X	
DCS Personnel	X	
DCS Logistics	X	
DCS Comptroller	X	X
Management and Costs Analysis	X	X

Fig. 1 Population/Universe Definition

AFCS staff and the target population is that portion of the staff shown in Figure 1.

The universe was defined based on the assumption that identification of goals and objectives must begin at the strategic level, in this case the Headquarters AFCS staff. The population represents those headquarters staff agencies sharing primary responsiblity for AFCS CEM engineering and installation management.

In addition, subpopulations were defined as shown in Figure 2. The reason for defining subpopulations was to recognize the different management information needs of each organizational grouping and to facilitate data collection and analysis.

Because the size of the population was small and located at one base, Scott Air Force Base, Illinois, a census approach for data collection was used.

The Data

The data for this research consisted of primary and secondary data. Primary data included responses from interviews with the target population and the personal observations of the researchers. Secondary data included books, theses, periodicals, and scholarly journals addressing the general subjects of performance indicators, effectiveness measurements, productivity measurements or output measurements. Additional sources included AFCS publications and correspondence.

Subpopulation 1

Command Section

Subpopulation 2

DCS Engineering and Programs
DCS Comptroller

Subpopulation 3

Program Control
Engineering
Program Management
Management and Cost Analysis

Fig. 2. Population-Subpopulation Definition

The Criteria for the Admissibility of the Data

Primary Sources. Responses from interviewees were accepted provided the interviewee had at least one year experience in the past five years in managing engineering and installation programs at major air command (AFCS), intermediate command (Communications Areas), or at EI group/squadron level. This criterion was intended to assure credibility of the interview (or interviewee).

Secondary Sources. This type of data was accepted from authors who contribute to scholarly journals and periodicals in the area of management science. Official AFCS correspondence and publication relating to EI goals were accepted as valid sources.

The Specific Treatment of the Data for Each Research Question

Research Question 1: What are the goals and objectives of the Headquarters AFCS staff for engineering and installation of CEM systems?

The methodology for research question one was broken down into six parts: relationship to the problem statement, definition of terms, data needed, location of data, the means for obtaining the data, and treatment of the data. The overall scheme for answering research question one is shown in Figure 3.

Relationship to the Problem Statement--Research Question 1

An answer to this research question is intended to provide the conceptual framework for identifying performance indicators.

Definition of Terms

Goal. For the purpose of this study, a goal is defined as:

> . . . plans expressed as results to be achieved. In this broad sense, goals include purposes, missions, objectives, targets, quotas, deadlines, etc. Goals represent not only the end point of planning but the end toward which other managerial activities, such as organizing and controlling, are aimed . . . . [28:440].

There is one primary goal: that is, to improve engineering installation management. The many subordinate

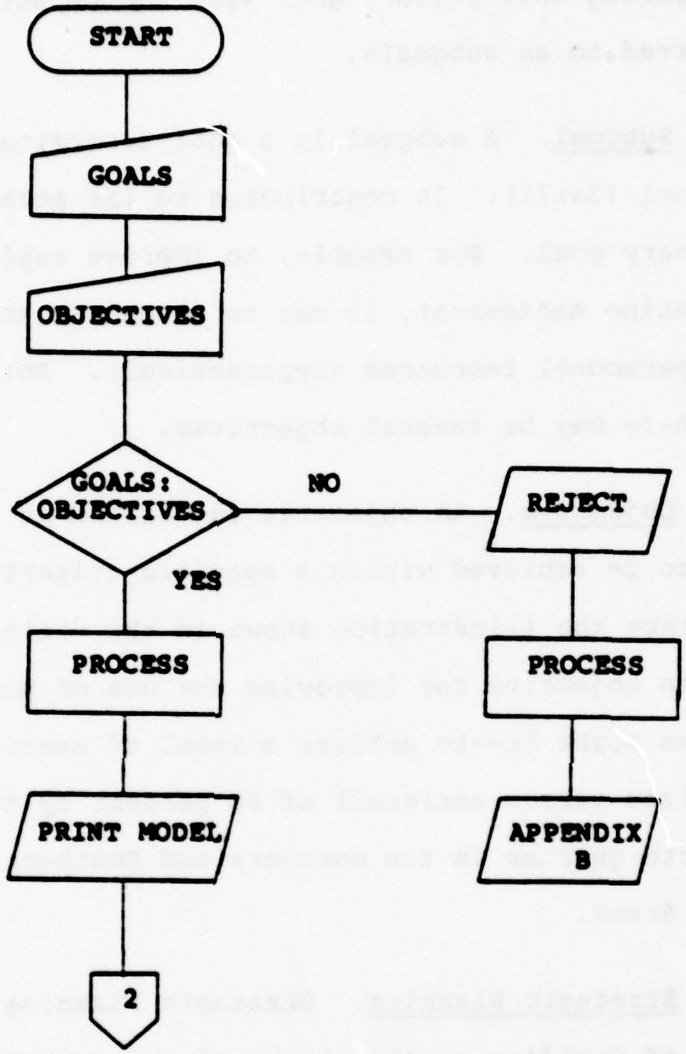

Fig. 3. Research Question 1 Scheme

goals linking this primary goal with the objectives will be referred to as subgoals.

Subgoal. A subgoal is a goal subordinate to the major goal (34:71). It contributes to the attainment of the primary goal. For example, to improve engineering installation management, it may be necessary to improve use of personnel resources (hypothetical). For each subgoal, there may be several objectives.

Objective. An objective is defined as a specific result to be achieved within a specific criterion (3:136). To continue the illustration shown in the definitions above, an objective for improving the use of personnel resources might be--*to achieve a level of manning* (authorized versus assigned) of 90 percent by the end of the fourth quarter in the Northern and Southern Communications Areas.

Strategic Planning. Strategic Planning is the process of deciding on objectives of the organization, on changes in these objectives, on the resources used to attain these objectives, and on the policies that are to govern the acquisition, use, and disposition of these resources (2:24)

Management Control. Management Control is the process by which managers assure that resources are

obtained and used effectively and efficiently in the accomplishment of the organization's objectives (2:17).

Operational Control. Operational Control is the process of assuring that specific tasks are carried out effectively and efficiently (2:17).

Strategic Focus. Strategic focus implies that the objective involves policy-setting, has long-range impact, may not be under the direct control of AFCS, and is of general interest to staff officers, analysts, and program managers at Headquarters AFCS or higher level.

Management Focus. Management Focus means that the objective involves procedures, programs or activities which can be directly controlled by AFCS, and are of general interest to commanders, line officers, and AFCS program managers. The emphasis is on program, people, and resources.

Operations Focus. Operations Focus means that the objective is of interest to commanders, team chiefs, and supervisors. The emphasis is on the task, scheme, job, and time.

Data Handling/Data Management. Data Management involves management information systems and subsystems.

Data Needed

The data needed were the subgoals and supporting objectives which will contribute to improving Headquarters AFCS management of engineering and installation programs.

Location of Data

The data were located at Headquarters AFCS, Scott Air Force Base, Illinois.

The Means for Obtaining the Data

Part of the data was obtained by conducting interviews with the target population using the questions shown in Appendix A. The remainder was obtained by screening AFCS publications and correpondence. The interviews were conducted on 19 and 20 March 1979. A tape recorder was used to assure the essence of the interview was not lost.

The Treatment of the Data

The data collected, which was used to construct the models shown in figures 4 and 5, was analyzed using these rules:

1. Subgoals were accumulated and placed in homogeneous groupings by subpopulation.

2. Each subgoal was subjectively compared with the definition of subgoals described previously. Those not consistent with the definition were not included in the model.

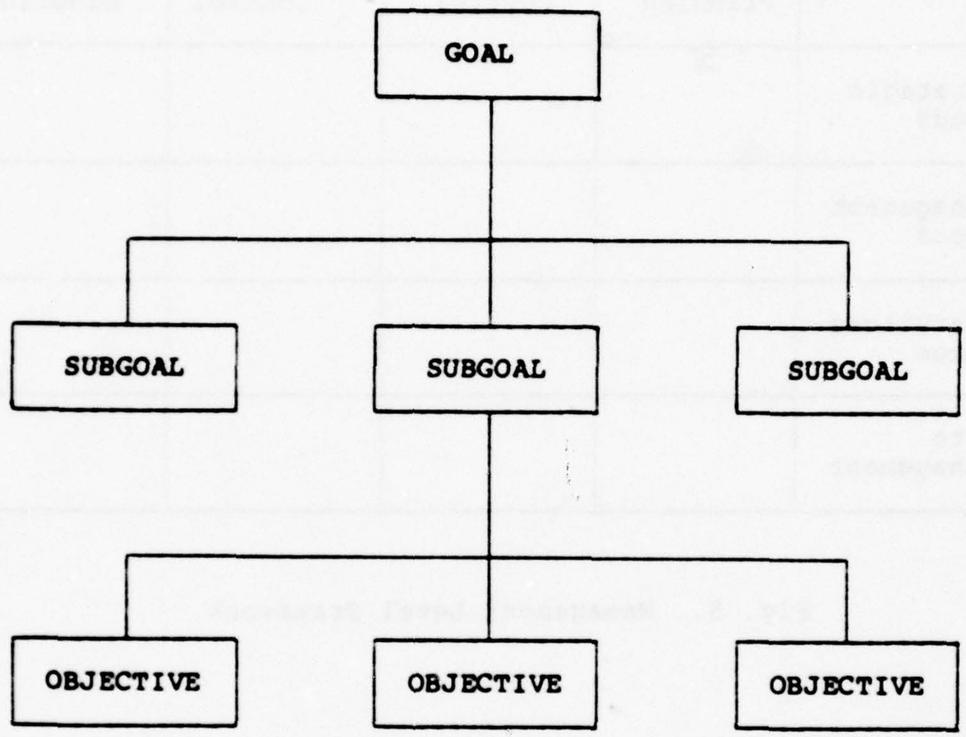

Fig. 4. Hierarchical Framework

	Strategic Planning	Management Control	Operations Control	Data Handling
Strategic Focus				
Management Focus				
Operations Focus				
Data Management				

Fig. 5. Management Level Framework

3. Each subgoal was subjectively compared with the overall goal. If the subgoal did not relate to the goal, the subgoal was not included in the model.

4. The subgoals were subjectively examined for duplication. Where duplication existed, the subgoals of subpopulation 1 took precedence over all the others and subpopulation 2 took precedence over subpopulation 3.

5. Each subgoal was assumed to be independent.

6. Screening of objectives was conducted as described in paragraphs 1 through 4 above.

7. Each objective was subjectively compared with the definitions of strategic planning, management control, operational control, and data handling.

8. Each objective was subjectively compared with the definitions of strategic focus, management focus, operations focus, and data management focus.

9. Each objective was matched with each subgoal based on the judgment of the researchers.

10. Once these matches were completed the hierarchical and management level frameworks were developed.

11. Subgoals with no related objectives were excluded from the hierarchical model and included in Appendix B.

The answer to Research Question 1 forms the baseline for Research Question 2.

Research Question 2: What EI performance indicators support the goals and objectives of the Headquarters AFCS staff?

The methodology for Research Question 2 is broken down into six parts: relationship to the problem statement, definition of terms, data needed, location of data, the means for obtaining the data and treatment of the data. The overall scheme for answering Research Question 2 is shown in Figure 6.

Relationship to the Problem Statement--Research Question 2

The answer to this research question leads to the completion of the hierarchical framework.

Definition of Terms

Performance Indicator. For the purpose of this study, a performance indicator is ". . . an element of an activity that can be measured, and when given a numerical value, might serve to measure progress toward an objective . . . [34:83]." To continue the illustration used previously in defining "goal," "subgoal," and "objective," the related performance indicator is shown in Figure 7.

Data Needed

The data needed were: performance indicators produced by the existing AFCS management information system

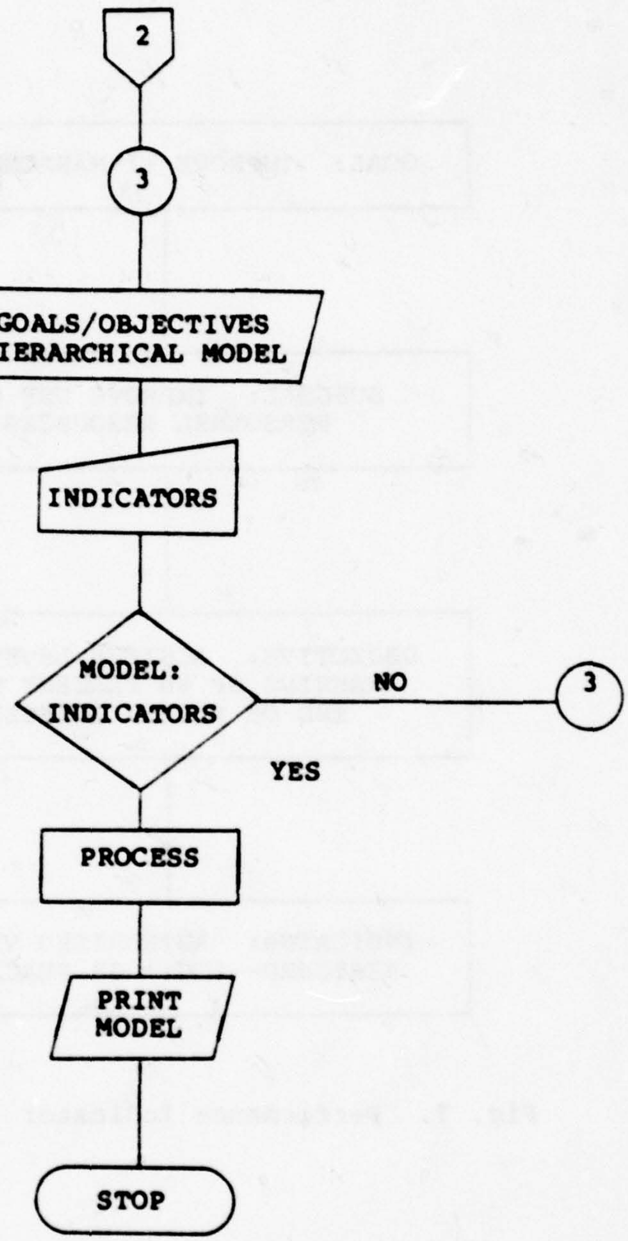

Fig. 6. Research Question 2 Scheme

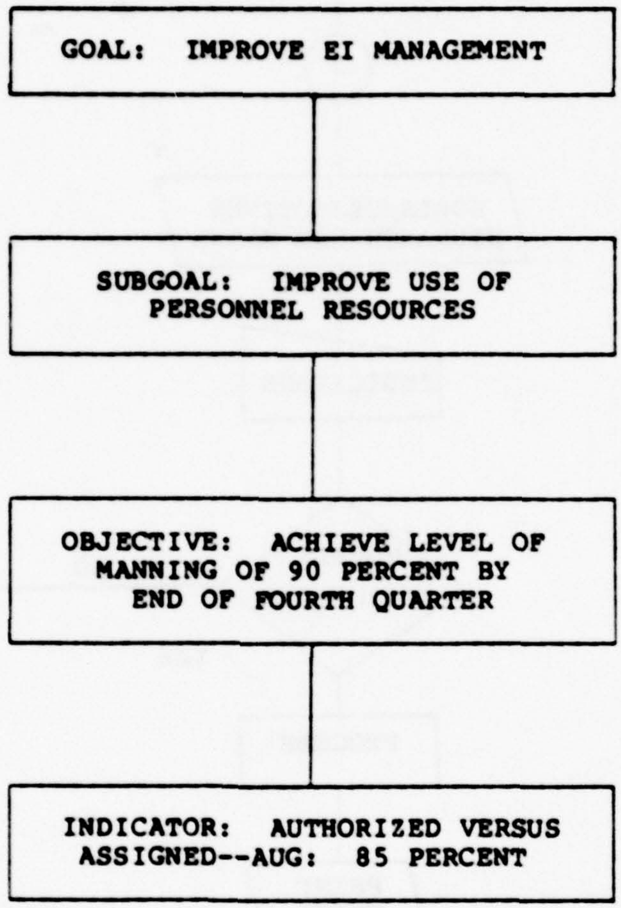

Fig. 7. Performance Indicator Illustration

(EIMS), AFCS Programming Plan 9-78 (Introspective Look), AFCSR 178-3, and any other AFCS management reports.

Location of Data

The data were located at Headquarters AFCS, Scott Air Force Base, Illinois.

The Means for Obtaining the Data

The data were obtained by screening AFCS publications and conducting interviews with the target population.

Treatment of the Data

The data collected were used to complete the model shown in Figure 8 using these rules:

1. Each indicator was subjectively compared with the definitions described previously.

2. In the case where there was an objective with no formal indicator, an indicator was recommended by the researchers.

Assumptions

The following assumptions were made in developing this methodology:

1. That at least one year's experience in the past five years was sufficient evidence to qualify a member's response for admissibility.

2. That responses to the structured interviews were honest and reliable.

3. That the population defined was all inclusive.

4. That the real goals were found.

SUBGOAL	OBJECTIVE	INDICATOR	REFERENCE

Fig. 8. Indicator Source List

CHAPTER IV

ANALYSIS AND FINDINGS

In mid-March 1979 the research team traveled to Scott Air Force Base, Illinois, and interviewed the members of the headquarters staff most concerned with EI management. During the course of these interviews, many people mentioned a special AFCS project known as Introspective Look.

Introspective Look was started in early 1977 as a four-phase project that had as its goal the determination of methods of improving the overall efficiency and effectiveness of the AFCS mission in the 1980s. It encompassed an in-depth self-analysis of all AFCS functions and included action items and milestones. A copy of the action items pertaining to EI management was obtained to gain greater insight into the project (25:1).

In addition, the team procured copies of AFCSR 178-3, "AFCS Management Information System," which outlined the current command standards and reporting system, and copies of several other publications and letters dealing with EI management. All of this information was then taken back to the Air Force Institute of Technology for further analysis.

By reviewing the interview notes and tape recordings and by following the methodology established in Chapter III, a definite pattern of goal congruence appeared. However, the significance of this congruence did not become really clear until the analysis of the Introspective Look project and the other AFCS publications was completed.

At that time, it became apparent that much of this clear vision and general harmony on what needed to be done to improve EI management could be traced to the Introspective Look project.

Objectives could be readily matched to the goals expressed by the Headquarters AFCS staff because specific objectives had been already established in response to the Introspective Look findings.

It was found that AFCSR 178-3 also complemented the goals and objectives. It identified and focused attention on key elements of mission performance and resource utilization, furnished current and projected performance data, and provided a means for preparation and presentation of summary management data (22:1-1).

Another factor which may have contributed to this general consensus was a recent policy letter which set forth the command position on issues related to the quality of EI life, a subject considered of major

significance in keeping EI personnel efficiently and effectively productive (30).

Hierarchical Framework

A hierarchy of goals, objectives, and indicators was developed based on the interviews and various AFCS publications and correspondence.

Goals

It was clear from the interviews that the primary Headquarters AFCS goal for Engineering and Installation was to improve EI management (29). This general impression was confirmed by the overall goal of the Introspective Look project: ". . . to determine methods of improving the overall efficiency and effectiveness . . . " of the AFCS mission (25:1). The theme of Introspective Look was to determine where AFCS is today and where it should be going tomorrow (25:1). In other words, it was an attempt to find goals and objectives. Although Introspective Look supported a singular goal, there was no attempt to show a direct relationship between this singular goal and the countless number of subordinate and linking subgoals involved in the project. However, based on the interviews and reviews of the Introspective Look audits, a series of linking subgoals were identified to facilitate development of the hierarchical framework.

All the data point out that to improve EI management a dual effort appeared to be necessary: to improve resource management and to improve data management. The hierarchy shows these subgoals (see Figure 9) as discrete; however, the two goals were related because the AFCS staff seemed to believe that further improvements in resource management were only possible with an improvement in data management (29).

There were three major subgoals which contributed to improved EI resource management: improvements in the utilization of people and organizational alignments, improvements in the effective and efficient use of materiel resources, and improvements in effective and efficient EI service.

Improvements in the utilization of people and organizational alignments were major concerns among nearly everyone interviewed. These concerns were generally in the area of improving quality of EI life, updating organizational functions, and enhancing the command's training programs (29).

Although not as predominant as the personnel and organizational issues, there was concern over the effective and efficient use of materiel resources. Specifically, there was a need to upgrade and modernize EI equipment. This issue also surfaced to the command-level from subordinate units in connection with the quality of

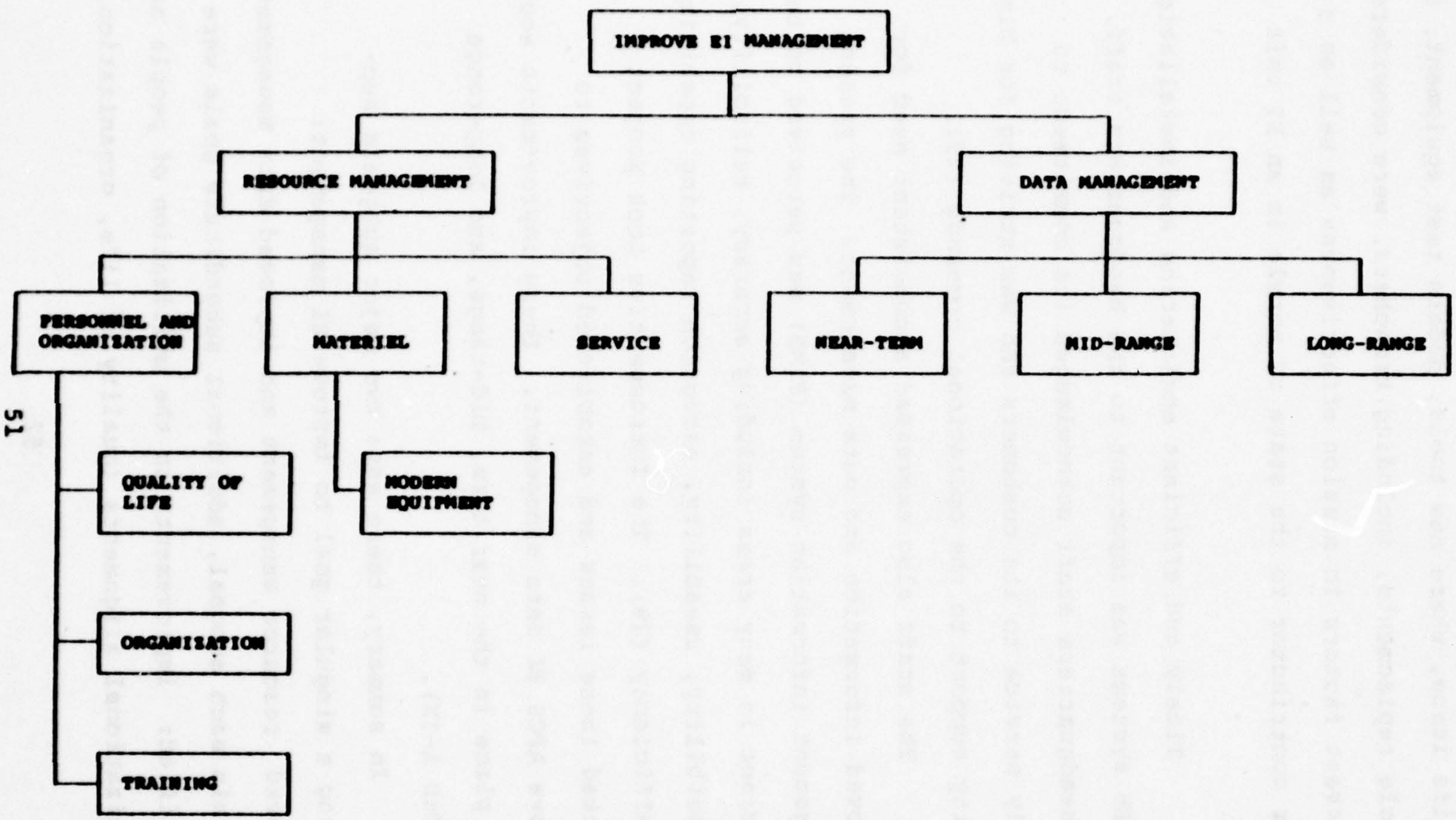

Fig. 9. Hierarchy of Subgoals

EI life issue, where new tools, modern test equipment, and vehicle replacments, including trenchers, were considered important factors in mission effectiveness as well as a major contributor to the state of morale in an EI unit (30).

Timely and efficient engineering and installation of CEM systems was important to the headquarters staff. The headquarters staff acknowledged its commitment to timely service to its customers and was striving for high quality support to the operational commands (29).

The staff also expressed a consistent need for improved information and data management. The present management information system (EIMS) was perceived to be deficient in many areas including accuracy, reliability, accessibility, useability, exception reporting capability, and efficiency (29). The Introspective Look project attacked these issues and established objectives to improve AFCS EI data management. These improvements would take place in the near term, mid-range, and long-range (20:Tab A-IX).

In summary, there were two major subgoals supporting a singular goal to improve EI management: improved resource management and improved data management. Within each subgoal, additional subordinate goals were identified: improvements in the utilization of people and organizational alignments (quality of life, organization,

and training); improved materiel management, effective and efficient EI service; and near-term, mid-range, and long-range data management improvements.

Objectives

Thirty-eight objectives supporting the subgoals discussed above were identified. Most of these objectives were obtained from AFCS publications and correspondence. Similar to relationships among goals, the relative position of objectives in the hierarchical framework may be misleading in that each block implies each objective is independent of all others, but as with goals, this was found to be not true. For example, objectives in the quality of life area have a direct relationship to objectives under effective and efficient use of materiel resources and it should be understood that the quality of a technician's job may be influenced by the condition of his/her tools and equipment.

Nine objectives were identified which supported AFCS efforts to improve the quality of EI life (see Figure 10): waiting spouse program, EI orientation, staff/site visits, host support, TDY, EI patch, team chief seminar program, E-5/6 TDY accommodations, and travel entitlements. In late 1978, the AFCS commander solicited support among subordinate units to take specific actions designed to improve quality of life and minimize the

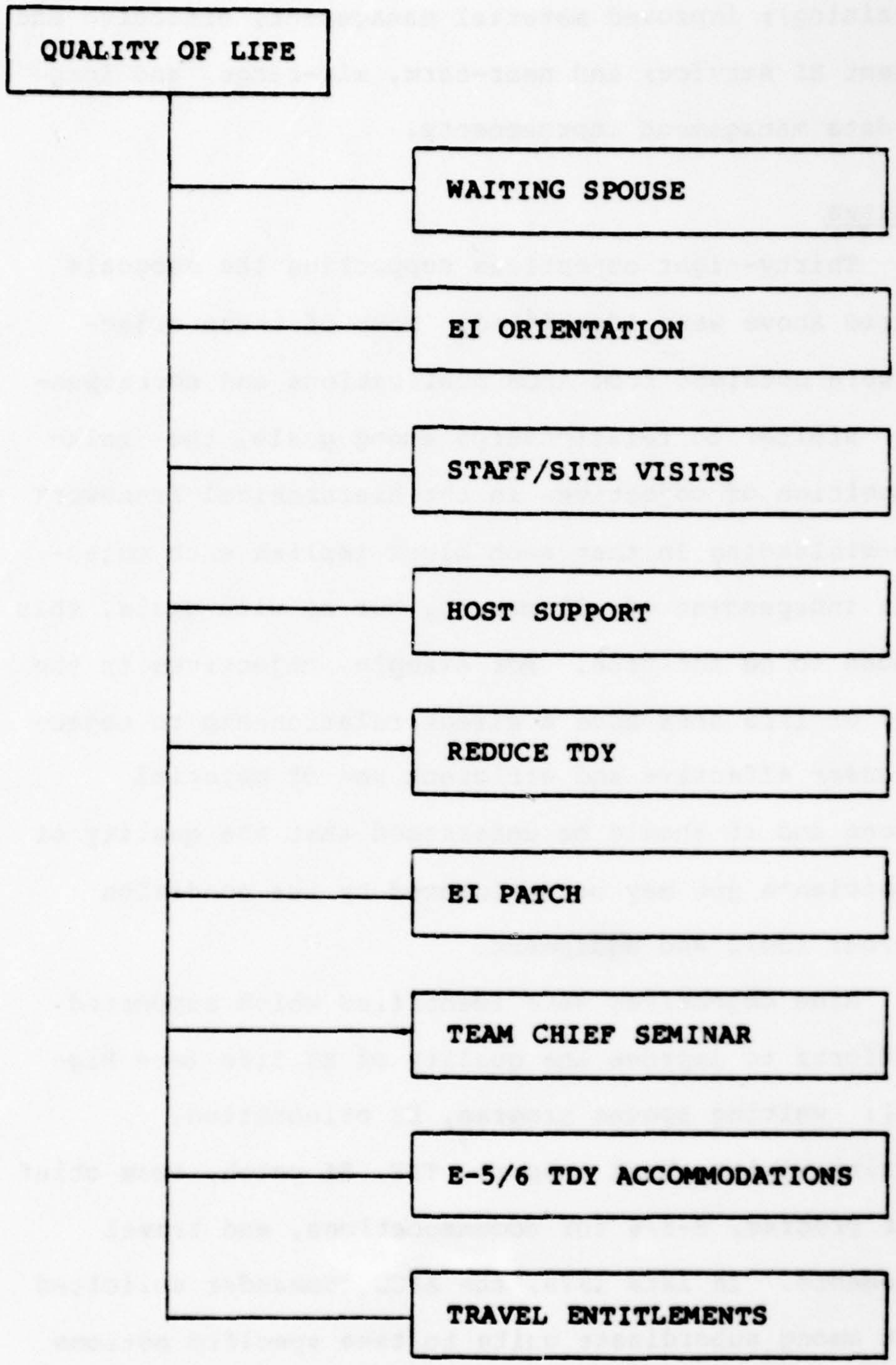

Fig. 10. Quality of Life Objectives

". . . impact of frequent and extended TDY and insure that personnel are adequately supported while TDY [26]."

The first of these actions (objectives) was a program to assist waiting spouses of EI team members who are on extended TDY. Another objective was for local units to set up a special orientation program for EI people to cover such things as travel voucher preparation, tax assistance, and obtaining help from installation services activities. A third objective was to ensure adequate support to deployed teams by encouraging subordinate commanders to personally visit work sites and assure all assistance needed by the deployed team was available. A related objective was directed to commanders receiving support from EI teams (host support). These commanders were asked to assist EI teams in arranging transportation, obtaining local assistance and local services (26).

To minimize the impact of an inherent EI TDY burden, the command had set out to increase the pool of skilled installers. The idea here was that there would be more people to share the TDY burden, thereby reducing TDY for each individual. To increase unit cohesiveness and pride in the unique mission EI is involved in, the command was also exploring the possibility of an EI patch or badge for the uniform (30).

As a means of providing a forum for expressing their concerns, team chiefs as representatives from each

Area, will have the opportunity to attend annual team chief seminars. The command and team chiefs should mutually benefit from such a forum (30).

Another important command objective was the need to improve the quality of EI life by obtaining authority from the Air Staff to allow private TDY accommodations for E-5/6 team chiefs. In fact, the entire subject of travel entitlements was a matter of concern. Legislation has been introduced in Congress to correct the inequities of travel entitlements among civilians, enlisted members, and officers. Successful passage of that legislation would be viewed as a major contributor to an improved quality of EI life (30).

In the AFCS Introspective Look project, several organizational (see Figure 11) issues were discussed and objectives were established to achieve organizational efficiencies. Among the objectives were realignments and consolidations of units to reduce overhead functions. This would allow a reduction in the number of EI organizations resulting in better use of scarce personnel resources by shifting nonproductive overhead people into installation skills (20:2-2).

Another related objective was established to reduce supervisory/administrative overhead. AFCS expects to achieve this objective by fine tuning the efficiency

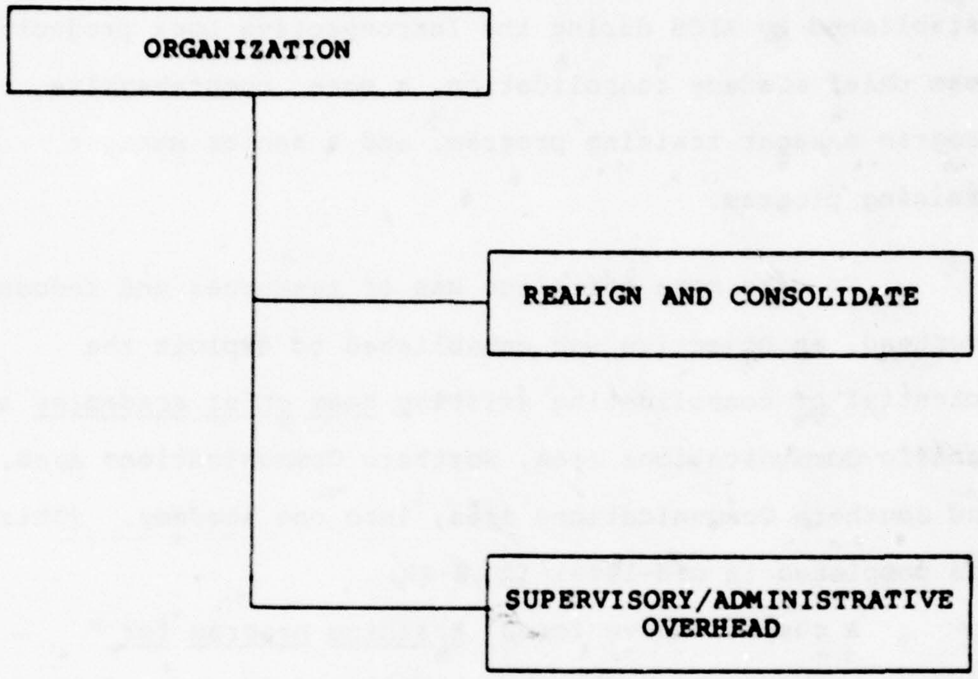

Fig. 11. Organization Objectives

and effectiveness within Area and group/squadron organizational structures (20:2-9).

To enhance the effectiveness and efficiency of training (see Figure 12), three objectives were established by AFCS during the Introspective Look project: team chief academy consolidation, a more comprehensive program manager training program, and a senior manager training program.

To make more efficient use of resources and reduce overhead, an objective was established to exploit the potential of consolidating existing team chief academies at Pacific Communications Area, Northern Communications Area, and Southern Communications Area, into one academy. (This was completed in mid-1979) (20:2-4).

A comprehensive formal training program for program managers needed to be established in view of the emphasis on program management. The program would include indoctrination and seminar training. Senior managers would be encouraged to complete special and follow-on training. This could include attendance at such schools as the Defense Systems Management College, DOD Computer Institute, and the U.S. Army Management Engineering Training Activity (21:2-2).

After conducting the interviews and reviewing the supporting documentation for the engineering and programs segments of the Introspective Look project, the researchers

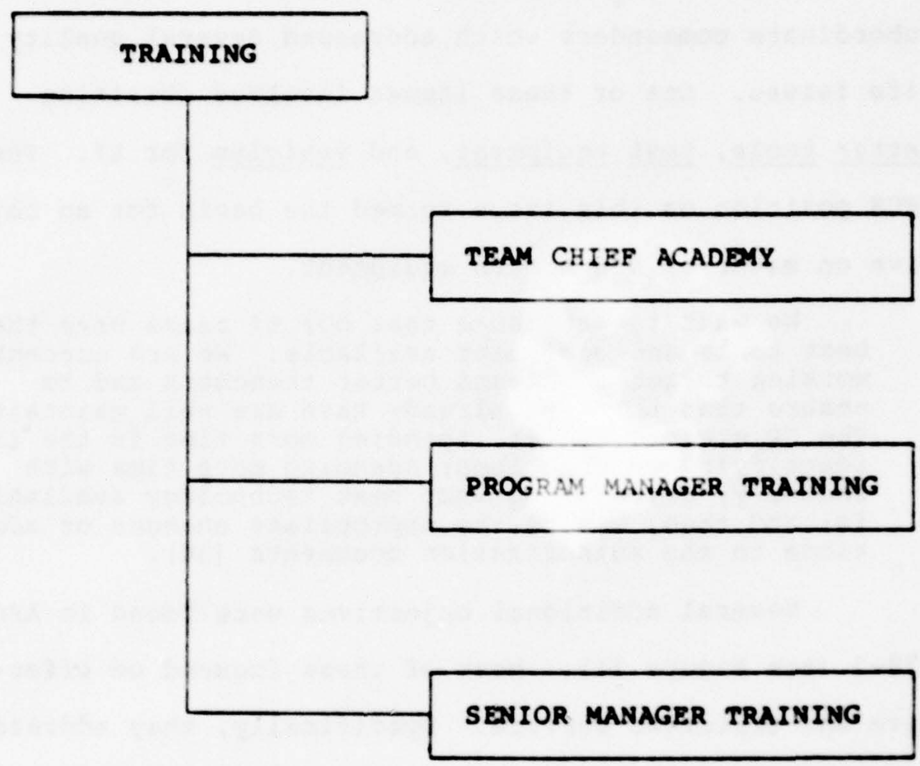

Fig. 12. Training Objectives

found very few goals or objectives in the area of materiel management (see Figure 13). However, a subgoal and several objectives were identified during a review of the AFCS Vice Commander's response to a letter he sent to subordinate commanders which addressed several quality of life issues. One of these issues involved obtaining better tools, test equipment, and vehicles for EI. The AFCS position on this issue formed the basis for an objective on materiel and modern equipment.

> We want to make sure that our EI teams have the best tools and equipment available. We are currently working to get our teams better trenchers and to ensure that those we already have are well maintained. The EP staff will be: spending more time in the field identifying the problems; spending more time with industry; determining what best technology available is; and then, making the appropriate changes or additions to the authorization documents (30).

Several additional objectives were found in AFCSR 178-3 (see Figure 14). Most of these focused on effective and efficient service. Specifically, they addressed these general subject areas: installer/maintainer utilization; engineering workload versus capability; installation/maintenance workload versus capability; held in abeyance (HIA) workoad; timely completion of schemes; and Headquarters AFCS and area managed programs. The objectives for each of these subjects are shown in Table 1.

Four objectives supported a near-term goal to achieve improvements in data management (see Figure 15). These improvements focused on the staff's ability to

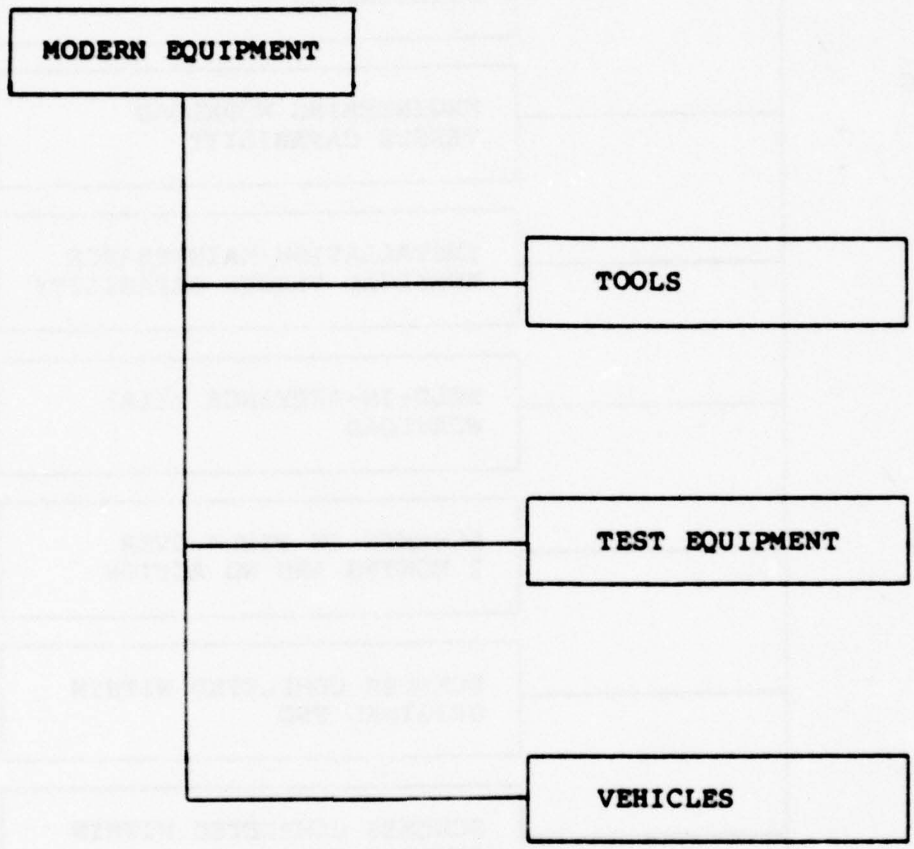

Fig. 13. Materiel Objectives

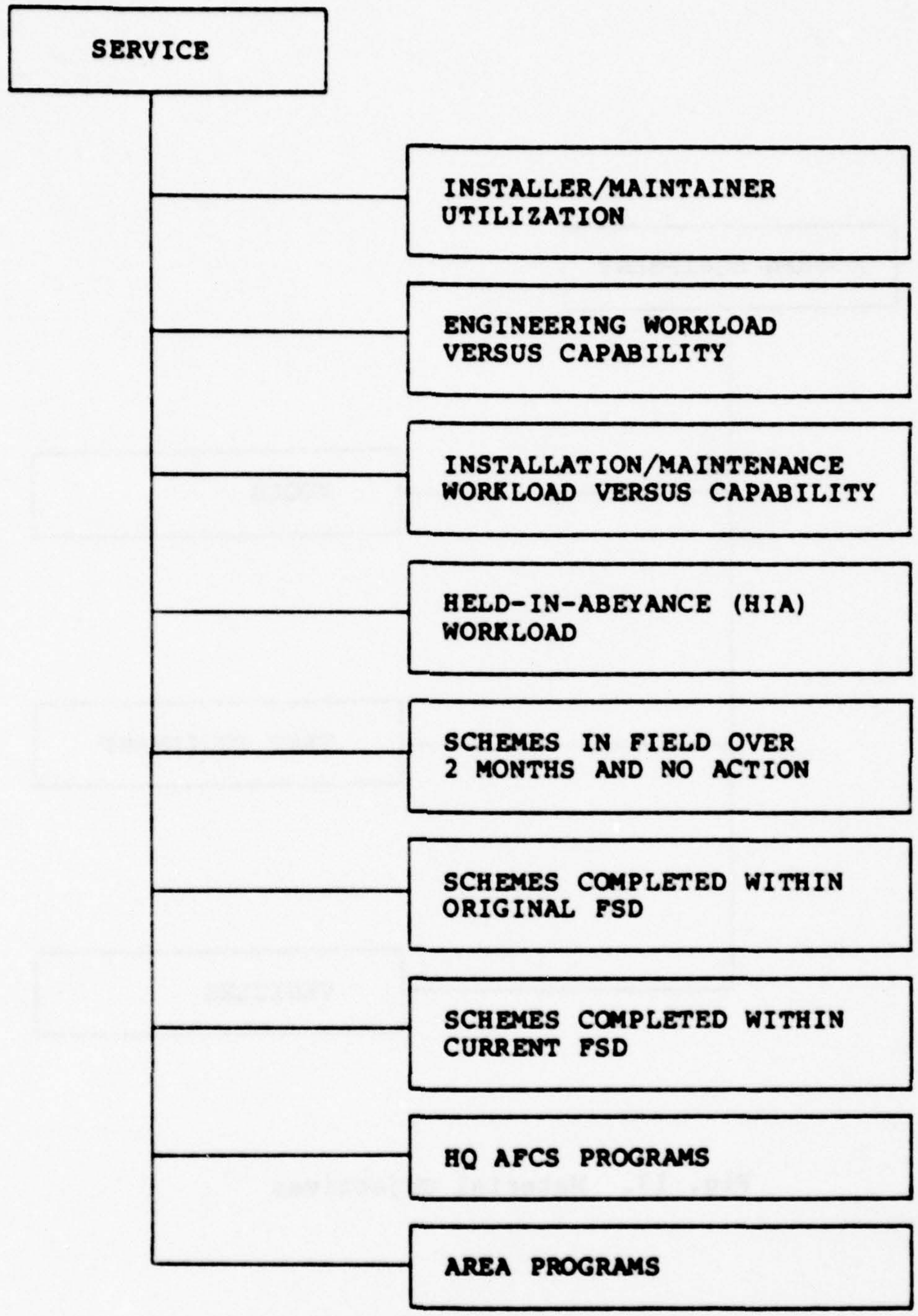

Fig. 14. Service Objectives

TABLE 1

SERVICE OBJECTIVES

Subject	Objective	Purpose
<u>Installer/Maintainer--utilization</u>	Maintains 100% direct labor utilization of the total available installer and maintainer man-hours.	Measure effective utilization of the EI direct labor force.
<u>Engineering Workload versus Capability</u>	Program and schedule workload to assure maximum utilization of manpower within limits of authorized manning.	Input source to the decision-making process on workload management.
<u>Installation/Maintenance Workload versus Capability</u>	Program and schedule workload to assure maximum utilization of manpower within limits of authorized manning.	Input source to the decision-making process on workload management.
<u>Held-in-Abeyance (HIA) Workload</u>	Maintain not less than 95 percent of all programs on schedule.	Detect adverse trends.
<u>Schemes</u> in field over two months and no action.	Reduce the number of fully supplied schemes in the field over two months in which installation has not begun to no more than 150.	Reduce premature callouts and allow resources to be allocated to more pressing jobs.

TABLE 1--Continued

Subject	Objective	Purpose
Schemes completed within original FSD.	Complete at least 50% of all schemes within the original FSD.	Detect adverse trends.
Schemes completed within current FSD.	Complete at least 85% of all schemes within the current FSD.	Detect adverse trends.
Headquarters AFCS-managed programs.	Maintain not less than 95% of all programs on schedule.	Detect adverse trends.
Area-Managed programs.	Maintain not less than 95% of all programs on schedule.	Detect adverse trends.

SOURCE: (22:3-9 through 3-14)

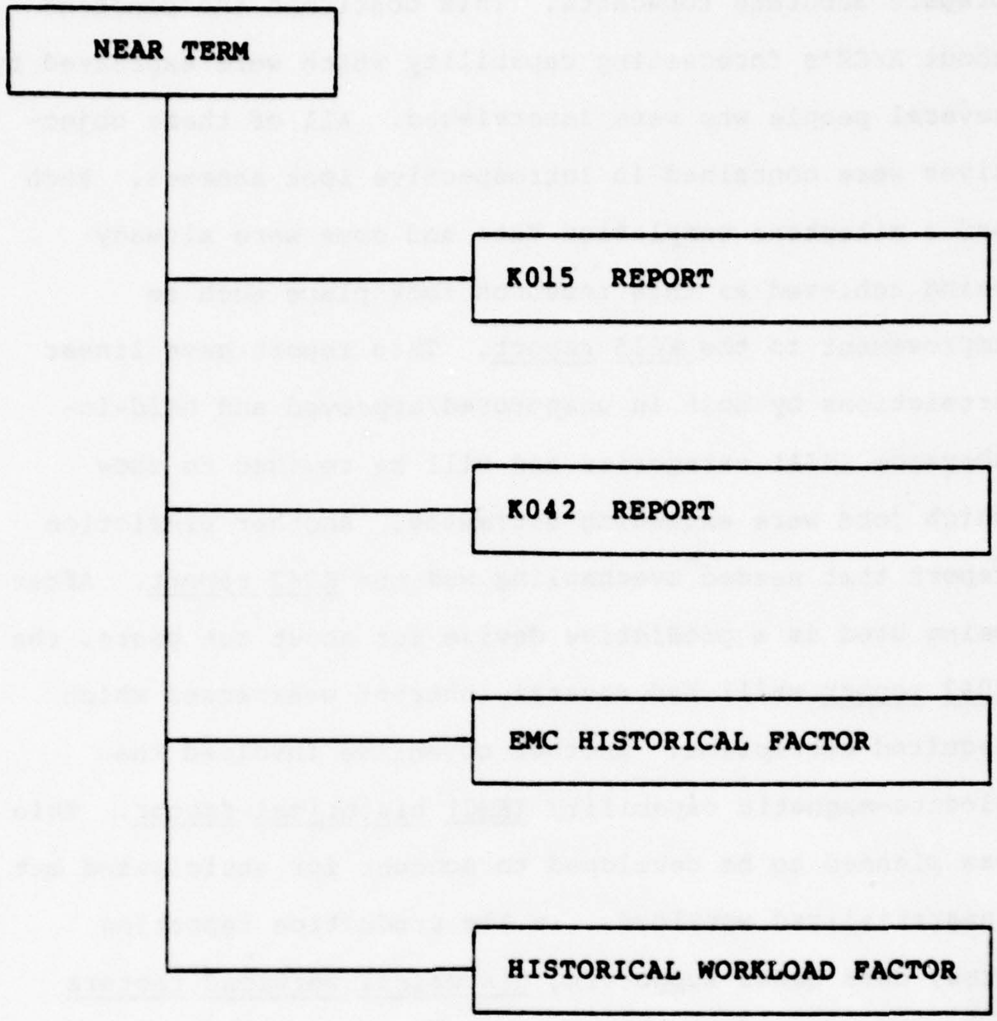

Fig. 15. Data Managment Near-Term Objectives

prepare accurate forecasts. This confirmed the concerns about AFCS's forecasting capability which were expressed by several people who were interviewed. All of these objectives were contained in Introspective Look annexes. Each had a milestone completion date and some were already being achieved as this research took place such as improvement to the K015 report. This report gave linear predictions by unit in unapproved/approved and held-in-abeyance (HIA) categories and will be revised to show which jobs were exceeding estimates. Another prediction report that needed overhauling was the K042 report. After being used as a predictive devise for about ten years, the K042 report still had several inherent weaknesses which required correction. Another objective involved the electro-magnetic capability (EMC) historical factor. This was planned to be developed to account for anticipated but unmaterialized workload. In the production reporting area, data banks supporting historical workload factors needed to be expanded for nonproductive time which occurred when a team was deployed (20:2-10).

There were seven objectives which contributed to mid-range data management improvements (see Figure 16). A brief description of each follows:

Effectiveness measurements are needed to ". . . correct the Parkinson's Law problem we find in units [20:2-10]." Concurrent with this effort, AFCS wanted

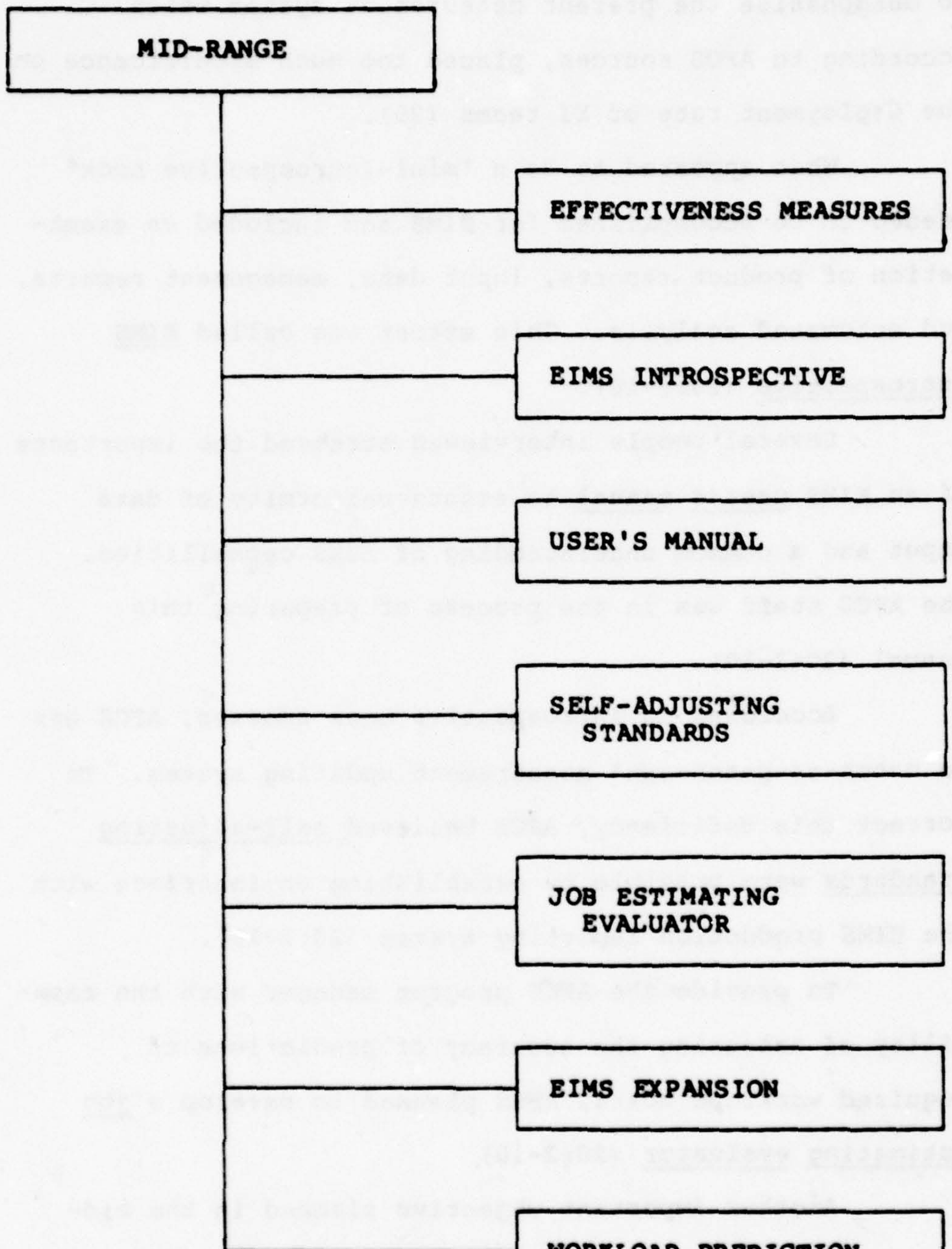

Fig. 16. Data Management Mid-Range Objectives.

to deemphasize the present measurement system which according to AFCS sources, placed too much significance on the deployment rate of EI teams (29).

What appeared to be a "mini-Introspective Look" needed to be accomplished for EIMS and included an examination of product reports, input data, management reports, and automated analysis. This effort was called EIMS Introspective (20:2-10).

Several people interviewed stressed the importance of an EIMS user's manual to assure uniformity of data input and a common understanding of EIMS capabilities. The AFCS staff was in the process of preparing this manual (20:2-10).

According to Introspective Look annexes, AFCS has "a catch-as-catch-can" measurement updating system. To correct this deficiency, AFCS believed self-adjusting standards were possible by establishing an interface with the EIMS production reporting system (20:2-10).

To provide the AFCS program manager with the capability of assessing the accuracy of predictions of required workload hours, AFCS planned to develop a job estimating evaluator (20:2-10).

Another important objective planned in the mid-range was EIMS expansion. AFCS planned to add program aggregation, cost tracking, a history and program formulation to the EIMS system. This was a software effort (20:2-10).

Finally, AFCS was also planning to use Command, Control, and Communications program data as a basis for a future workload prediction system (20:2-10).

In the early 1980s, AFCS planned to complete implementation of applied system automation through the EIMS Program Improvement Concept (EPIC) (see Figure 17). This effort which is a project to replace the B-3500 processing at the local level, will impact on the credibility, accessibility, utility, flexibility, timeliness, and accuracy of the engineering and installation management information system (20:2-10).

In summary, thirty-eight EI objectives were identified. Twenty-six of these were resource management oriented: fourteen in personnel and organization, three in materiel, and nine in effective and efficient EI service. The remaining twelve were involved in data management improvements: four in the near-term, seven mid-range, and one long-range. These formed the framework for identifying indicators.

Indicators

Once the objectives were identified, indicators began to fall in place. An indicator was found or recommended for each objective--a total of thirty-eight. Of the thirty-eight, seventeen were controlled and prescribed by AFCS Programming Plan 9-78, nine by AFCSR 178-3, and

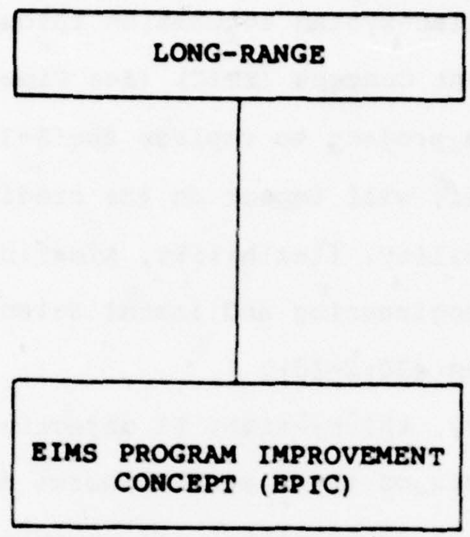

Fig. 17. Data Management Long-Range Objectives

twelve which involved policy compliance were recommended by the researchers.

The indicators controlled by AFCS Programming Plan 9-78 related to organization, training, and data management objectives. Annex B to the Plan set up a management information system to control and report progress toward achieving these objectives. The progress reports translate to management indicators. Reporting began in January 1979 (25).

The indicators (Table 2) controlled by AFCSR 178-3 related to the effective and efficient performance of EI service. In this regard, AFCSR 178-3 sets up a system for collecting, analyzing and reporting management information pertaining to operations and resource management.

The objectives associated with quality of life, either directly or indirectly as with the materiel objectives, are not part of a formal management information and control system. Compliance with these objectives must be measured subjectively either by the Inspector General, staff assistance visits, or an informal report. The indicator can take on a dichotomous form: i.e., "Yes, a program exists, or "No, it does not." A "yes" answer would be followed by an evaluation describing program effectiveness. A "no" answer should be accompanied by rationale for noncompliance.

TABLE 2

SERVICE INDICATORS

Objective/Subject	Indicator
Installer/Maintainer Utilization.	Installer/Maintainer utilization percentage.
Engineering Workload versus Capability	Program versus schedule.
Installation/Maintenance Workload versus Capability.	Program versus schedule.
Held-in-Abeyance (HIA) Workload	Number of HIA jobs versus total jobs.
Schemes in field over two months and no action.	Number of schemes.
Schemes completed within original forecast support date (FSD).	Percentage of scheme completed within original FSD.
Schemes completed within current FSD.	Percentage of schemes completed within current FSD.
Headquarters AFCS-managed programs.	Percentage of programs on schedule.
Area-Managed Programs	Percentage of programs on schedule.

SOURCE: (22:3-9 through 3-14).

In summary, at least one indicator was identified for each of the thirty-eight objectives. All but twelve indicators are presently incorporated in formal AFCS management information control systems. A source list for each indicator is shown in Table 3.

Management Levels Framework

An additional perspective was gained by looking at the objectives in terms of Anthony's management levels framework: strategic planning, management control, operations control, and data handling. Table 4 shows each objective classified by management levels and grouped by the objective's focus: strategic, management, operations, and data management.

The researchers found that over 40 percent of the objectives identified have a strategic focus; about 35 percent have a management focus; nearly 20 percent have operations emphasis, and the balance (5 percent) are purely data management.

Strategic

There are three objectives considered strategic planning with a strategic focus: better tools, test equipment, and vehicles. Staff officers at command level or above would be primarily concerned about assuring these requirements are planned, programmed, and budgeted. The strategic focus is appropriate for this reason and

TABLE 3

INDICATOR SOURCE LIST

Subgoal	Objective	Indicator	Reference
Resource Management			
Personnel & Organization			
Quality of Life			
	Waiting Spouses	Compliance	(26)
	EI Orientation		
	Staff/Site Visits		
	Host Support		(26)
	Reduce TDY		(29)
	EI Patch		
	Team Chief Seminar		
	E-5/6 TDY Accommodations		
	Travel Entitlements	Compliance	(29)

TABLE 3--Continued

Subgoal	Objective	Indicator	Reference
Organization			
	Realign and Consolidate	On/Off Schedule	(25)
	Supervisor/Administrative Overhead	On/Off Schedule	(25)
Training			
	Team Chief Academy	On/Off Schedule	(25)
	Program Manager Senior Manager	On/Off Schedule	(25)
Materiel			
Modern Equipment			
	Tools	Compliance	(29)
	Test Equipment Vehicles	Compliance	(29)

TABLE 3--Continued

Subgoal	Objective	Indicator	Reference
Service			
	Installer/Maintainer Utilization	Expended vs. Assigned	(22)
	Engineering Workload vs. Capability	Approved vs. Authorized	
	Installation/Maintenance workload vs. Capability	Approved vs. Authorized	
	Held-in-Abeyance (HIA) Workload	Number of Jobs in HIA vs. Total Jobs	
	Schemes in field over 2 months & no action	No more than 150	
	Schemes Completed within original and current FSD	Completed vs. Required	
	HQS APCS Programs	On Schedule vs. Total	
	Area Programs	On Schedule vs. Total	

TABLE 3--Continued

Subgoal	Objective	Indicator	Reference
Data Management			
Near-Term			
	K015 Report	On/Off Schedule	(25)
	K042 Report		
	EMC Historical Factor		
	Historical Work-load Factor	On/Off Schedule	(25)
Mid-Range			
	Effectiveness Measures	On/Off Schedule	(25)
	EIMS Introspective		
	User's Manual		
	Self-Adjusting Standards		
	Job Estimating Evaluator		
	EIMS Expansion		
	Workload Prediction	On/Off Schedule	(25)

TABLE 3--Continued

Subgoal	Objective	Indicator	Reference
Long-Range			
	Epic	On/Off Schedule	(25)

TABLE 4

OBJECTIVES BY MANAGEMENT LEVEL AND FOCUS

Focus	Management Levels			
	Strategic Planning	Management Control	Operations Control	Data Handling
STRATEGIC	Tools Test Equipment Vehicles	EI Patch E-5/6 TDY Accommodations Travel Entitlements		K015 Report K042 Report EMC Historical Factor Historical Workload Factor EIMS Introspective Self-adjusting Standards Job Estimating Evaluator EIMS Expansion Workload Prediction EPIC

TABLE 4--Continued

Focus	Management Levels			
	Strategic Planning	Management Control	Operations Control	Data Handling
MANAGEMENT		Staff/Site Visits Host Support Team Chief Seminar Realign & Consolidate Supervisory/ Administrative Team Chief Academy Program Manager Training Senior Manager Training Installer/Maintainer Utilization Workload vs. Capability (2) AFCS Programs Area Programs		

TABLE 4--Continued

Focus	Management Levels			
	Strategic Planning	Management Control	Operations Control	Data Handling
OPERATIONS		Waiting spouse EI Orientation Reduce TDY	Held-in-Abeyance Workload Schemes in field over two months no action Schemes Completed within original FSD Schemes Completed within current FSD	
DATA MANAGEMENT			Effectiveness Measures	User's Manual

EI: Engineering and Installations
EIMS: Engineering Installation Management System
EPIC: EIMS Program Improvement Concept
FSD: Forecast Support Date

Blank by Definition

additionally, because approval for funds comes from levels lateral to or above Headquarters AFCS.

In management control, there are three objectives with strategic focus: distinctive EI patch, private accommodations for E-5/6 team chiefs, and achieving equitable travel entitlements. Commanders are primarily interested in these quality of life objectives, but the approval authority is outside AFCS channels. Commanders can only extend their support for policy changes to higher echelons. Therefore, timing of this support and the rationale justifying the change are crucial factors and any management indicator must recognize these considerations. An indicator here would take the form of a tickler to the commander. For example, any trip he would make to the Air Staff could include a visit to the office of primary responsibility to obtain the latest status of the action.

Over half the objectives with strategic focus are involved with data handling: The K015 report, K042 report, EMC historical factor, historical workload factor, EIMS introspective, self-adjusting standards, job estimating evaluator, EIMS expansion, workload prediction, and EIMS Program Improvement Concept (EPIC). The primary and immediate beneficiary for these data management improvements will be the headquarters staff. But in the long run

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there should be an improvement in the effectiveness and efficiency of all EI management.

Management

Thirteen of the thirty-eight objectives are in the management control category and have a management focus. Three objectives are quality of life, three training, two organizational, and five are EI service-oriented. In the case of the quality of life, training, and organization objectives, AFCS has primary control over the resources and can influence the outcome of the objective. The five EI service-oriented objectives are measures of aggregate productivity, workload management and program scheduling. They provide commanders (Area and above) and program managers with macro, trend-type measures of effectiveness. These are appropriate for acquiring perspective but have little value in controlling EI elements.

Three management control objectives have an operations focus: waiting spouse program, EI orientation, and TDY reduction. These objectives support the quality of life subgoal and are a part of management control as a result. They have an operations focus because primary responsibility for implementation rests with the local commanders and supervisors.

Operations

Only seven operations control objectives were included in the hierarchical framework and four were in operations control. They involve scheme management and are intended to be an aggregate measure of customer satisfaction.

Data Management

One of the operations control objective has a data management focus: identification of effectiveness measurements. As discussed previously, the Introspective Look project had established the requirement to develop effectiveness measurements to ". . . identify and correct the Parkinson's Law problem (found) in units [20:2-10]."

The final objective with a data management focus is the publication of the EIMS user's manual.

In summary, the management levels framework shows that the objectives identified have a strategic and management focus. Management control objectives are basically management oriented but also have a strategic and operations flavor. Less than 20 percent of the objectives are operations oriented. Nearly all the data handling objectives have a strategic focus.

Synthesis

The two frameworks just described present some interesting relationships. Each has its own set of

advantages and disadvantages. Together, they lay the foundation for further study and analysis and support the need to exploit modeling/simulation as management aids. This is consistent with remarks made by Anthony in his preface to Planning and Control Systems--A Framework for Analysis:

> . . . I kept recalling the point that President James B. Conant demonstrated so vividly in On Understanding Science, namely, that development of a framework or a conceptual scheme often has led to progress, "even though the framework turns out to be wrong." Isolated experiences and discrete bits of knowledge are not very useful. When organized into some kind of pattern, however, the pieces often illuminate one another; the whole becomes greater than the sum of its parts. The very act of organization may show the framework itself is defective. Nevertheless, the framework will have served a useful purpose if it prepares the way for a better one (3:VIII).

The hierarchical framework clearly shows a unity of effort where each objective ultimately contributes to a greater singular purpose. Viewed in this context, vertical relationships are clear. One can understand that the headquarters staff recognizes that improved resource management and improved data management are needed to improve the overall management of engineering and installation of CEM systems. What now may seem obvious could have been not so obvious to the many people who support the AFCS mission. The hierarchical framework places every indicator in context and has the potential of providing subordinate managers with a grand view of the goals of the entire organization.

But there are also many shortcomings with this framework. It tends to obscure horizontal relationships. Training and organization objectives contribute to quality of life and many of the data management objectives contribute to improving EI service. Another problem is that the framework may not be all inclusive. Another example is that even though the quality of allied support affects the EI mission, it was omitted based on its relative importance and to delimit the problem to manageable proportions. Finally, the hierarchy is static and must be updated to keep pace with changes in the philosophy of top management. This particular hierarchy is a point-in-time snapshot as of March 1979.

The management levels framework classifies objectives by the functions of management. In this context, it does an excellent job of exposing management emphasis or lack of it as measured by the number of objectives. This analysis reveals that the emphasis is on strategic and management level objectives and that there is ample evidence to support a distinct lack of emphasis on operations-oriented objectives. This comes as no surprise since the Headquarters AFCS staff is considered to be a strategic level function. Perhaps the framework's strongest attribute is that it places the various indicators in perspective.

The framework has several shortcomings. It does not illustrate either horizontal or vertical relationships. Each objective appears to be an independent entity. As shown previously, this is not a valid assumption. Another problem is that the model does not show a unity of effort.

In summary, taken together the models show that there are seven operations indicators and four support the command's goal of improving the effectiveness and efficiency of EI service. These indicators are not time sensitive and are highly aggregated.

As a result of the interviews, it was found that mangement not only wanted this aggregate view of EI performance as shown by the operations' indicators, but expressed a need to know, on an exception basis, when an unplanned slippage or delinquency in meeting a milestone has a significant impact on program or scheme completion dates (29). This desired characteristic of performance measurement would provide a signal to the manager at the time a milestone is missed and then forecast impact on the outcome of the scheme. Such an indicator is conspicuously absent from the framework described above. This points to the need to enhance the hierarchical and management level frameworks by exploiting the use of modeling/simulation.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The reliability and effectiveness of communications systems is important to military commanders in the execution of peace and wartime operations. This has focused considerable emphasis on having the most modern CEM facilities and equipment. A key element in assuring the reliability and effectiveness of these communications systems is properly managed engineering and installations projects.

Despite a long and turbulent history, engineering and installation organizations have done an admirable job in keeping pace with the tremendous momentum of modernization. However, there is a growing concern that EI organizations may not be able to keep pace unless innovative steps are taken to improve EI management. Several recent inspector general and audit reports have uncovered numerous management problems and stated that some units are suffering due to inadequate tools and equipment and that morale of EI people is decaying as a result.

This situation, along with the desire for improved resource utilization, has been the reason AFCS has placed

increasing emphasis on improvements in resource and data management. The Headquarters AFCS quest for improving EI management blended well with AFIT's ability to provide needed research for USAF organizations and led to this attempt to find meaningful performance indicators for the engineering and installation of CEM systems.

The research started with a literature search that revealed several things. First, that the task of identifying performance indicators must begin by finding out the goals and objectives of the organization. This would show what the organization plans to do (goals) and how it plans to do it (objectives). Performance indicators would then be the signal which would show management how they were doing in achieving what they set out to do.

Secondly, the literature review revealed that the job of finding goals and objectives is difficult but can best be accomplished by following a systematic plan. This plan should lead to the development of frameworks of analysis. Some experts preferred a hierarchical framework, others a management level approach, and some preferred both. As James Conant puts it:

> . . . a conceptual scheme often has led to progress, "even though the framework turns out to be wrong." Isolated experiences and discrete bits of knowledge are not very useful. When organized into some kind of pattern, however, the pieces often illuminate one another; the whole becomes greater than the sum of its parts. The very act of organization may show the framework itself is defective. Nevertheless, the framework will have served a useful

purpose if it prepares the way for a better one [2:VIII].

Thirdly, the literature review revealed that a top-down approach is very important. This should begin with the strategic levels of the organization and proceed systematically to the operational levels.

Finally, the researchers learned that performance indicators can take many forms. They can measure quantity or quality, results or processes, trends or ratios, etc. Some are able to measure future capability while others focus on overall organizational performance and control.

Based on this extensive literature research, a methodology was developed which supported four specific objectives:

1. To determine Headquarters AFCS goals and objectives for the engineering and installation of complex CEM equipment.

2. To identify any existing performance indicators.

3. To compare existing indicators with identified goals and objectives.

4. To recommend any additional performance indicators which match the goals and objectives.

The detailed methodology was also based on the academic philosophy that a framework of analysis should be used in structuring the research. Both the hierarchical

and management level framework were applied to these research questions:

What are the goals and objectives of the Headquarters AFCS staff in the engineering and installation of CEM systems?

What EI performance indicators support the goals and objectives of the Headquarters AFCS staff?

To determine the goals of the Headquarters AFCS staff for the engineering and installation of CEM systems, numerous people of the Headquarters AFCS staff were interviewed. This interview approach was taken because it was the preferred approach among the contemporary authors in the management science field. Surprisingly, there was almost no disagreement among all the people interviewed on what the goals of EI were. But there was different emphasis placed on the various goals. It was found that this general consensus could be partially attributed to a recent AFCS effort called the Introspective Look.

Conclusions

Overall, the researchers found that there are two major subgoals supporting a singular goal to improve EI management: improved resource management and improved data management. Six major subgoals were found which link these overall goals to the objectives: improvements in the utilization of people and organizational alignments;

improved materiel management; effective and efficient EI service; and near-term, mid-range, and long-range data management improvements.

Thirty-eight objectives supporting these subgoals were found. All of these objectives were found in AFCS publications and correspondence such as Headquarters AFCS Programming Plan 9-78, AFCSR 178-3, AFCSR 500-11, and Headquarters AFCS/CV letter dated 24 January 1979. Twenty-six of the objectives support the resource management subgoal, while twelve support the data management improvement subgoal. In terms of management levels, there was a distinct focus on strategic and management levels with very little emphasis placed on the operations-oriented objectives. Strategic levels of any organization seldom get involved in operations matters; however, the Headquarters AFCS staff has expressed a need to become increasingly involved.

In response to the Headquarters AFCS need to become increasingly involved in the operations levels of EI, the researchers concluded that contemporary management science techniques should be considered for application as a performance indicator subsystem. Two techniques which have been applied to network processes like EI are described below in some detail; however, before discussing these techniques, a conceptual view of the subsystem is necessary.

Headquarters AFCS staff wants to become involved in operations level problems in order to take action which would prevent serious problems from developing. Also, to avoid the problem of information overload, reporting is essential because not all operations level problems require attention at the strategic levels. Some problems should be resolved at intermediate levels. Most should be corrected at the operations level. Therefore, a performance indicator subsystem must incorporate these features and perhaps include a long-range forecast of future impact as well as a current assessment. A conceptual illustration is shown in Figure 18.

As shown in the illustration, the performance indicator signals whether or not the current task is on schedule. In the initial comparison, current performance is tested against the assigned milestone. If the task is completed on schedule, no action is necessary and the process continues, and output results. But if the task is completed behind schedule, another assessment is accomplished to determine the impact of this slippage on the future outcome of the project. When there is no impact on the future outcome of the project, then no action is necessary. But when the future outcome is affected, then the decision-maker at the operations level is notified. The decision-maker then determines if the assistance of the Area commander is needed. If not

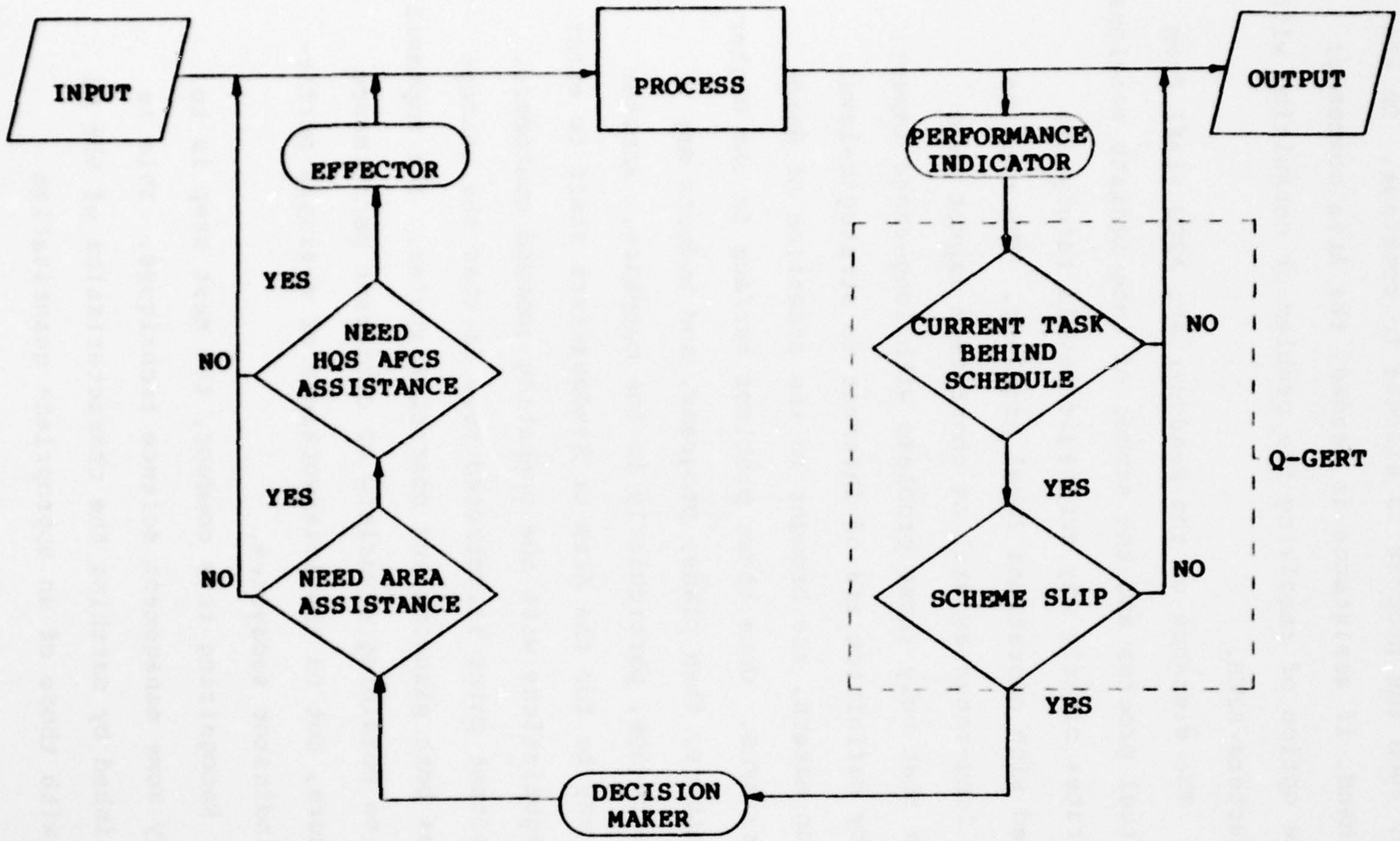


Fig. 18. Performance Indicator Subsystem

needed, then the process is allowed to continue. On the other hand, if assistance is needed, the Area commander has the option of resolving the problem or consulting with Headquarters AFCS.

The distance of the Headquarters AFCS staff from the actual process and the number of intermediate echelons illustrates clearly why strategic levels rarely are involved with operations level problems. The need to assess long-range as well as short-term impact also assures that only those problems with long-range impact, which by definition are of interest to strategic-level decision makers, are brought to the attention of Headquarters AFCS. Once these problems surface to the higher headquarters, then plans, programs, and budgets may require change, particularly in the outyears. Another action may be for the Area or Headquarters staff to enter into negotiations with the operating command customers. An important point illustrated here is that the concept combines both planning and control features. The emphasis is not on obtaining a variety of different performance indicators, but on the interworkings of a single performance indicator subsystem.

Recognizing this concept, the next step is to identify some management science techniques. This is accomplished by matching the characteristics of the EI system with those of an appropriate quantitative

technique. At the operations level, EI can be described as a generalized scheduling system. Figure 19 shows the general process involved in such a system.

A widely recognized technique compatible with a generalized scheduling process is the Program Evaluation and Review Technique (PERT). PERT was developed in the late 1950s by Clark and Frazier and has been used as a network technique for planning, replanning and control of long-term and nonrepetitive projects (38:128). In addition, it has the capability to support planning and control functions of management.

The PERT technique is a graphic portrayal of the project activities. Each activity, shown by a straight line, emanates and ends at a node. A node amounts to a milestone for completion of activity. The entire project is thus decomposed into self-contained and independent activities with nodes as milestones which require completion within stipulated times.

PERT can also be described as a model. It constitutes a body of information and restrictions about a unique situation for the purpose of rigorous study (6:368). According to Murdick and Ross, models are an important management science innovation because they:

> . . . can solve both simple and complex problems of the practical world (by focusing) on some key features instead of on every detail of real life. This approximation of reality (may be constructed) in various forms . . . [32:378].

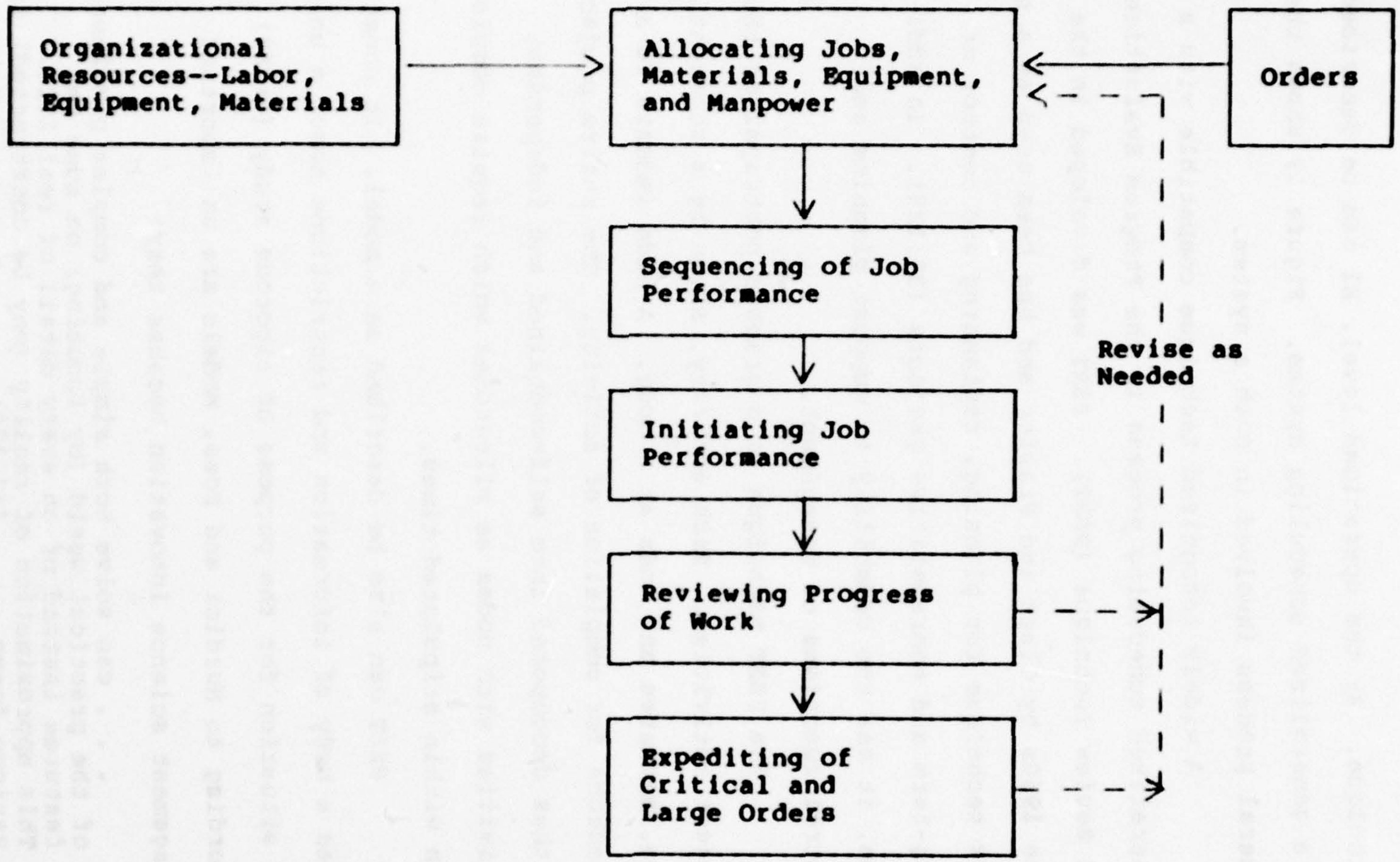


Fig. 19. Generalized Scheduling System (10:302)

There are many varieties of models. They can be an abstraction of the system by function, structure, line reference, organization, etc. They can be deterministic or probabilistic or employ both features. There are simulation-type models where ". . . the system's elements can be represented by arithmetic, analogic, or logic processes that can be executed, either manually or by computer, to predict the dynamic properties of the real system [10:274]."

Management scientists use a set methodology in constructing a model. This methodology considers the objectives of the system being studied, the variables which affect achievement of the objectives, the system parameters, decision rules, probability distributions, timing, and any statistical tests (10:275).

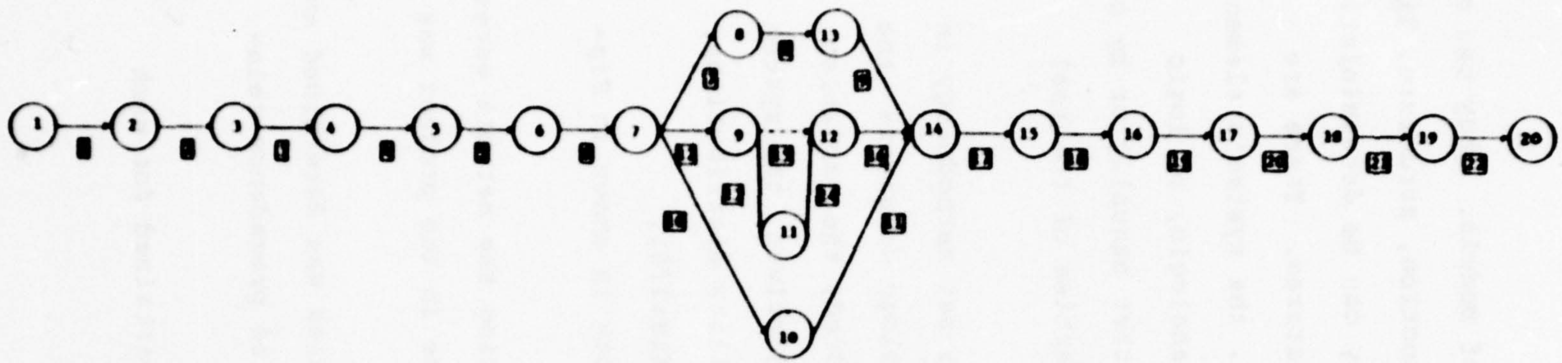
A representative PERT network is shown in Figure 20.

The steps used in constructing the network were:

1. Each activity to be done in the project was identified.

2. The sequence of activities was determined and a network constructed which reflected precedence relationships.

3. Time estimates were ascertained for each activity.



Activity No.	Name	Time Taken T_m	T_o	T_p	T_e	Activity No.	Name	Time Taken T_m	T_o	T_p	T_e
1	AFCS Processing	200	150	250	200	12	Group Project Analysis	25	15	40	26
2	AFLC Interface	120	90	180	125	13	Problem Identification	15	10	30	17
3	Air Staff Approval	150	100	190	148	14	Problem Rectification	45	20	100	50
4	AFLC/AFSC Interface	30	20	55	33	15	Dummy	0	0	0	0
5	Area Actions	90	45	120	88	16	Job Scheduling	20	15	30	21
6	Engineering Survey	30	20	50	32	17	Pre-Installation Survey	8	5	15	9
7	Material Identification	90	40	120	87	18	Discrepancy Correction	30	8	90	36
8	Material Ordering	15	10	30	17	19	Installation	40	20	80	43
9	Material Shipment	100	80	300	103	20	Testing	10	3	30	12
10	Allied Support	90	40	150	92	21	Rectification	10	2	20	10
11	Allied Support Completion	100	70	300	102	22	Acceptance	2	1	5	2

Fig. 20. EI PERT Network (Sample)

4. The expected time (ET) for each activity was calculated using the basic PERT estimating formula:

$$ET = \frac{a+4m+b}{6}$$

where:

a = the optimistic time estimate

b = the pessimistic time estimate

m = the most likely time

5. The variances (σ^2) of each activity time were calculated using another basic PERT estimating formula:

$$\sigma^2 = \left(\frac{b-a}{6}\right)^2$$

6. The critical path which is an important feature of PERT was then determined. It is the longest sequence of connected activities through the network (10:551).

The activity timing estimates were established by questioning experienced people in an EI workload control function. T_m represents the most likely time for completion of the concerned activity, while T_o and T_p are the optimistic (earliest expected completion time) and the pessimistic (longest expected time that the activity could take) respectively. T_e is the weighted average.

The critical path for the illustration begins, of course, with activity 1 and extends to 2, 3, 4, 5, 6, 7, 8, 9, 17, 18, 19, 20, 21, and 22. The estimated completion date for the project would be estimated to be 1,025 days after AFCS assumed project responsibility.

Now suppose the project has actually begun and the first two activities have been completed. This process would begin by comparing actual completion dates of each activity with the scheduled completion dates and the critical path recomputed to take into account the actual times. The resulting revised forecasted completion date would be compared with the original forecast which would provide the decision-maker with advance warning of an impending program slippage.

Although this seems to be a fairly straightforward technique, it is based on several rigid assumptions: that all activities be completed before an event can be realized, that no events be repeated, that all activities be completed, that time estimates follow a Beta distribution, and that the critical path avoids the possibility of variances even though they may exist (39:265). These rigid assumptions limit the practicality of the model.

There is a less widely known technique which can be applied to the same type systems and under the same conditions as PERT but relaxes these rigid assumptions.

This technique is known as Q-GERT (Queuing-Graphical Evaluation and Review Technique).

Q-GERT is a FORTRAN-based computer assisted modeling/simulation technique based on the network approach to modeling. It is an outgrowth of PERT which is the classic example for network analysis and provides an excellent basis for understanding Q-GERT.

In addition to a relaxation of PERT assumptions, Q-GERT offers ten statistical probabilities distributions (e.g., Poisson, Triangular, Normal, Erlang, etc.) which can be used in describing the behavior of a particular activity. By making excellent use of the theories of probability, a Q-GERT model has the potential of being a more real-life abstraction. It is also a simulation model unlike PERT.

Constructing the Q-GERT model follows generally the methodology for PERT except probability distributions must be specified for each activity (see Figure 21). This is frequently a difficult proposition and is considered by some management scientists to be a disadvantage (39:450). But specifying these distributions makes the abstraction more realistic.

Another strong point in favor of simulation and Q-GERT is that experiments can be conducted and through these experiments forecasts can be made more credible. For example, by using random time estimates for each

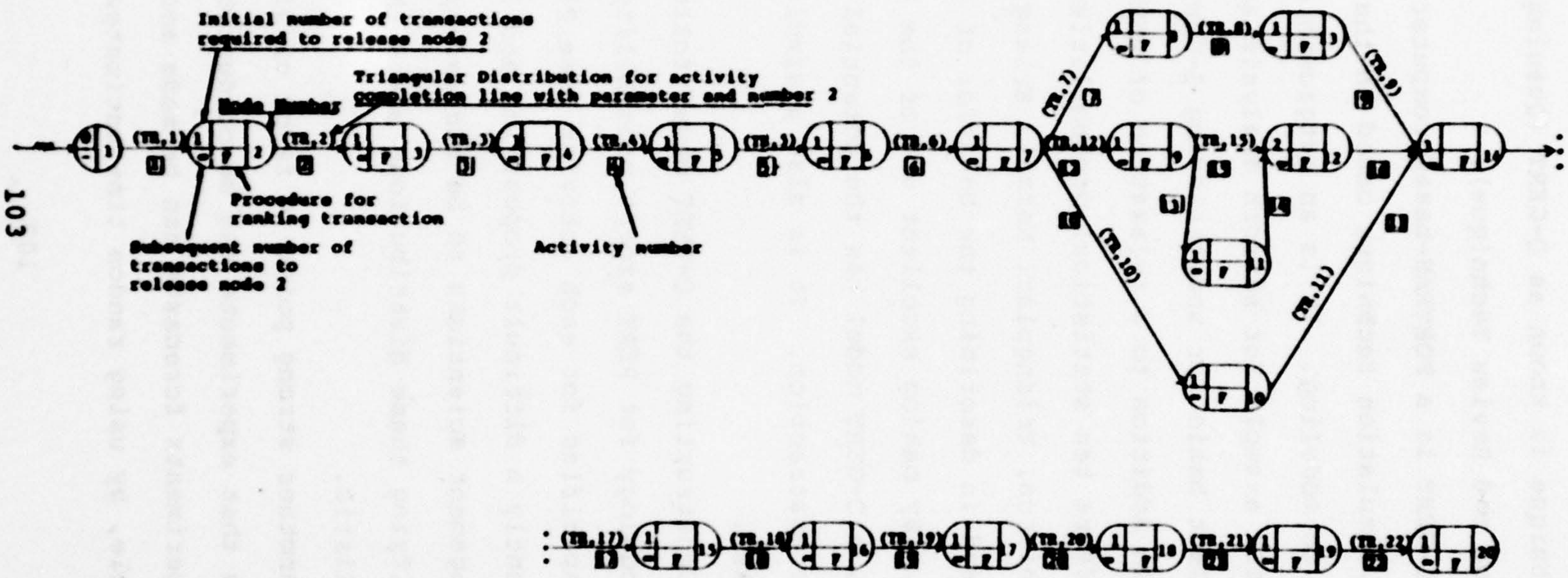


Fig. 21. EI Q-GERT Network (Sample)

activity, with prespecified parameters, several forecasts of project completion dates can be made. This can be done by exercising the model any number of times, e.g., 400, 500, or more times. Of course, EI projects are rarely repeated this number of times and most likely each project is unique in many ways. Incidently, this may be one reason why making EI workload forecasts based on historical data is so difficult. Simulation solves this problem. By running the model a large number of times, the forecasted completion date approaches a much more refined estimate. It is similar to having a historical file of actual data based on several perfectly similar projects with precisely the same individual tasks and activities. In this illustration, 500 trials were used and some of the forecasted completion probabilities are shown in the histograms contained in Table 5 and 6. Table 5 displays the planned probabilities before the project began. Table 6 displays the revised probabilities of the forecasted completion dates after actual dates have been entered into the model for the first five activities.

Recommendations

Identifying performance indicators for an organization as large and a system as complex as CEM engineering and installations must be carefully planned and systematically executed. One research project covering a relatively short-time horizon is certainly not sufficient.

TABLE 5

Q-GERT OUTPUT (FORECAST)

F STAT HISTOGRAM FOR NODE 20

NODE-20

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER BOUND OF CELL
2	0.004	0.004	900.00
2	0.004	0.008	918.00
5	0.010	0.018	936.00
7	0.014	0.032	954.00
18	0.036	0.068	972.00
24	0.048	0.116	990.00
33	0.066	0.182	1008.00
38	0.076	0.258	1026.00
55	0.110	0.368	1044.00
51	0.102	0.470	1062.00
59	0.118	0.588	1080.00
64	0.128	0.716	1098.00
47	0.094	0.810	1116.00
33	0.066	0.876	1134.00
27	0.054	0.930	1152.00
19	0.038	0.968	1170.00
7	0.014	0.982	1188.00
5	0.010	0.992	1206.00
3	0.006	0.998	1224.00
1	0.002	1.000	+INF

TOTAL 500			

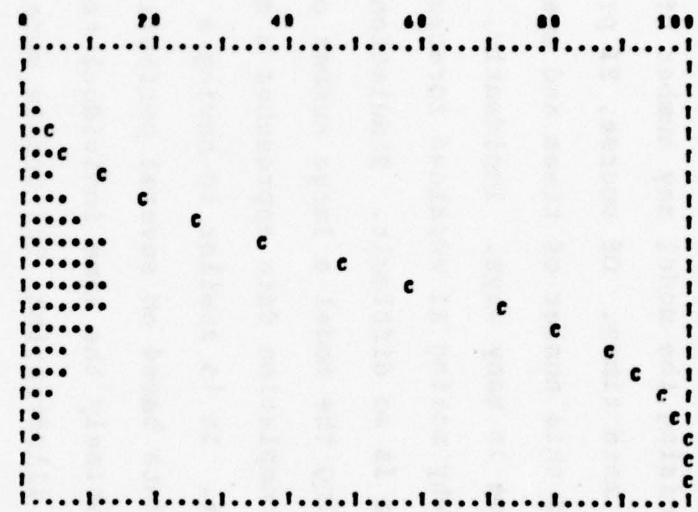


TABLE 6

Q-GERT OUTPUT REVISED (FORECAST)

```
F   STAT HISTOGRAM FOR NODE    20

               NODE-20

 OBSV     RELA     CUML         UPPER
 FREQ     FREQ     FREQ     BOUND OF CELL     0        20        40        60        80       100
                                              I....I....I....I....I....I....I....I....I....I....I
    0     0.       0.              900.00     I                                                 I
    0     0.       0.              918.00     I                                                 I
    0     0.       0.              936.00     I                                                 I
    0     0.       0.              954.00     I                                                 I
    4     0.008    0.008           972.00     I                                                 I
    8     0.016    0.024           990.00     I*                                                I
   22     0.044    0.068          1008.00     I**C                                              I
   27     0.054    0.122          1026.00     I***  C                                           I
   59     0.118    0.240          1044.00     I******     C                                     I
   75     0.150    0.390          1062.00     I*********          C                             I
   68     0.136    0.526          1080.00     I********                 C                       I
   68     0.136    0.662          1098.00     I********                        C                I
   66     0.132    0.794          1116.00     I********                               C         I
   48     0.096    0.890          1134.00     I******                                      C    I
   23     0.046    0.936          1152.00     I**                                            C  I
   18     0.036    0.972          1170.00     I**                                              CI
   10     0.020    0.992          1188.00     I*                                                C
    4     0.008    1.000          1206.00     I                                                 C
    0     0.       1.000          1224.00     I                                                 C
    0     0.       1.000             +INF     I                                                 C
                                              I....I....I....I....I....I....I....I....I....I....I
  ---
TOTAL     500
```

But it is a beginning. Therefore, the highest priority recommendation is that follow-on research be conducted to continue the top-down approach initiated by this research. An immediate follow-on research project should be done using the hierarchical and management level frameworks of analysis to identify performance indicators for the AFCS Communications Areas. This should provide a foundation for a second follow-on research project to identify performance indicators at engineering and installation groups/squadrons. In addition, the Headquarters AFCS staff should consider applying management science techniques such as PERT and Q-GERT to achieve improvements in the planning and control of EI programs.

APPENDIX A

INTERVIEW QUESTIONS

1. How much experience have you had in EI and at what level?

2. How long have you been in your current assignment?

3. If less than one year in your current assignment, have you been assigned to EI in the past five years?

4. What are your current EI responsibilities?

5. Who has primary staff responsibility for EI?

6. Who has collateral staff responsibility for EI?

7. How does EI contribute to the AF mission?

8. What management initiatives have been taken to improve EI in the past five years?

9. What new management initiatives to improve EI are on the horizon? (probe)

10. Are you satisfied with these new management initiatives and if not, what ones would you suggest?

11. What do you consider to be the major strengths of EI management?

12. What do you consider to be the attributes of the best Area/Group/Squadron?

13. What do you consider to be the attributes of the worst Area/Group/Squadron?

14. What do you consider to be the major weaknesses of EI management?

15. What types of problems take up most of your time?

16. What are your major funding problems?

17. What are your major personnel problems?

18. What are your major materiel problems?

19. What do you consider to be the major problems in engineering and installation today?

20. How do you plan to deal with these problems?

21. What, in your view, is the most important single goal for EI?

22. What, in your view, are the most important subgoals which contribute to achieving the overall goal?

23. What, in your view, are the most important objectives which will contribute to achieving each subgoal?

24. What do you consider to be the EI goals of the (Commander/DCS/Director/Division)?

25. What do you perceive to be the EI goals of your immediate subordinates?

26. How do you measure effectiveness?

27. How do you measure efficiency?

28. What measures of engineering effectiveness do you apply?

29. What measure of installation effectiveness do you apply?

30. Would you like to make any other comments?

APPENDIX B

EXCLUSIONS FROM FRAMEWORK

Framework Exclusions

Subject Area	Source	Exclusion Cause
Engineer Cooperative Program	Interviews	Lack of specificity
Control over host Support		
Random job/program reviews		
Central dispatching of skills		
Level of effort budgeting		
In-house versus contractng out		Beyond scope of this study

Framework Exclusions (Continued)

Subject Area	Source	Exclusion Cause
Combat communications/group training	AFCS Programming Plan 9-78	Beyond scope of this study
Program Management Procedures		
Realignment of program management (internal)		
Examination of program directives		
Capability to perform initial TRACALS evaluation in conjunction with installation		
EMC charter		
1842 EEG manning		
CCPC role in Autodin II		

Framework Exclusions (Continued)

Subject Area	Source	Exclusion Cause
Engineering workload/capability not balanced		
EIMS engineering manhour projection not consistent with expenditures		
Wrong work assigned work centers	AFCS Programming Plan 9-78	Not consistent with operational definitions
EI workforce exceeds EIMs projection		

Framework Exclusions (Continued)

Subject Area	Source	Exclusion Cause
Engineer manhour indicator		
Installer manhour indicator	AFCSR 178-3	Purpose and objective beyond scope of this study
Total force element indicator		
Materiel short lead time indicator		No objective
Materiel phase completion indicator		
Recognition of EI people	AFCS/CV letter 24 Jan 1979	Lack of specificity
WAPS-testing objective		Beyond scope of study

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